COOPERATIVE NATIONAL PARK RESOURCES STUDIES UNIT
UNIVERSITY OF HAWAI`I AT MĀNOA

Department of Botany
3190 Maile Way
Honolulu, Hawai`i 96822
(808) 956-8218

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VEGETATION MANAGEMENT STRATEGIES FOR THREE NATIONAL HISTORICAL PARKS ON HAWAI`I ISLAND

Linda W. Pratt

USGS Biological Resources Division
Pacific Island Ecosystems Research Center
Kilauea Field Station
P. O. Box 52
Hawaii National Park, HI 96718

University of Hawai`i at Mānoa
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Vegetation Management Strategies for Three National Historical Parks on Hawai`i Island

Summary

The need for vegetation management plans at the three National Historical Parks on the *Kona* coast of Hawai`i Island has been recognized by National Park Service managers at the Park, Cluster, and Regional levels. Problems associated with the absence of an organized management plan for vegetation were identified following 1994 scoping sessions focused on cultural landscape planning and resource zoning in the three Parks. Often cultural landscape plans precede vegetation management plans, as the desired landscape must be known before vegetation can be managed to restore the appropriate historical or cultural scene. However, in the case of the *Kona* Parks, it was clear that vegetation management was already well underway, and a plan was needed to help direct management activities to priority sites and to document goals for future management. Not all National Parks have vegetation management plans, and there is no standard format for such plans. For many Parks, the Resources Management Plan covers the management of vegetation, and a specific plan is not deemed necessary. For those Parks that have vegetation management plans, the plans fall into three categories: exotic plant management plans that focus on exotic or alien plant issues, site management plans that discuss only specific sites within the Park, and general vegetation management plans that cover topics of plant control and elimination, as well as restoration of an historical scene. The *Kona* Parks Vegetation Management Plan is of the latter type.

To initiate the vegetation management planning process for the three National Historical Parks of Hawai`i Island, a three-day scoping session was held in *Kailua-Kona* during September 1996. This session included site visits to all three Parks and group discussions on more than 20 topics related to vegetation management. Attendees were primarily National Park Service (NPS) personnel from Hawai`i units, the Pacific Islands Support Office in Honolulu, and the Regional Office in San Francisco, but researchers of the Biological Resources Division of the U. S. Geological Survey and the Cooperative Parks Studies Unit of the University of Hawai`i also participated. Much information was received on diverse management topics during the three-day session. Using the suggestions and input of the scoping session attendees and other advisors, an outline for the plan was developed. Priority sites to be the focus of vegetation management were selected at each of the three Parks, using both suggestions from scoping session attendees and previously written Park Service materials. Outlines and lists of priority sites were circulated to Park Superintendents and Resources Managers, and revisions were made after comments were received.

During the development of the plan, site visits were made to each of the three Parks. Previous surveys of vegetation and checklists of vascular plants for the three Parks were consulted (particularly Smith *et al.* 1986; Canfield 1990; Macneil and Hemmes 1977; Pratt and Abbott 1996a, 1996b, 1996c). Park Service documents, such as General Management Plans, Resources Management Plans, and Development Concept Plans, were invaluable aids to the vegetation management planning process. The recently compiled "Cultural History of Three Traditional Sites on the West Coast of Hawai`i Island" by Linda Greene with Diane Rhodes was a particularly rich source of cultural and archaeological information and pertinent literature citations. A group of Hawaiian advisors was consulted for suggestions on appropriate species to restore or outplant at Kaloko-Honokōhau NHP.

The following vegetation management plan is divided into three sections, with each section focused on one of the three *Kona* coast National Historical Parks. The order in which the three Parks are presented does not in any way imply importance or urgency. The plan starts with the southernmost of the Parks, Pu`uhonua o Hōnaunau National Historical Park (NHP), proceeds up the coast to Kaloko-Honokōhau NHP near *Kailua-Kona,* and ends with Pu`ukoholā National Historic Site near *Kawaihae.* Within each Park the plan

is organized into five basic sections: an introduction with background information on the history and site characteristics of the Park; a section on general strategies of alien plant control and native plant management and restoration; proposed vegetation management at priority sites, including recommendations for alien plant control and native/Polynesian plant restoration; alien vegetation management proposed for other non-priority Park sites or suggested for the entire Park; and a discussion of monitoring and research needs that will help direct future vegetation management. Within the priority sites and alien vegetation management sections, sites and alien plant species are not arranged in order of priority. All sites discussed are considered to be high priorities for management.

The issue of endangered plants and their management is discussed for each Park in the section on strategies of native plant management and in the restoration portion of the priority sites that currently have endangered species. General goals of alien plant control programs are also discussed in the section on vegetation management strategies. Recommendations for herbicide treatments are given in the section on priority sites when an effective treatment is known or current management utilizes herbicides; herbicides are discussed in the alien vegetation and/or research and monitoring sections when further research is required. It is understood that herbicide use in the *Kona* Parks will follow all Park Service regulations, State laws, and label restrictions and that Park workers using herbicides will be trained in proper application techniques and use of personal protection equipment. The mention of herbicide product names in the plan does not imply endorsement by the National Park Service or USGS/Biological Resources Division.

Appendices at the end of the plan include a categorized list of alien plant species to be managed at each Park, a checklist of vascular plant species recently found within the three parks, a report on pollen analysis at Kaloko-Honokōhau NHP written by University of Minnesota palynologists Christine Douglas and Sara Hotchkiss, and a report and viewshed analysis of Pu`ukoholā Heiau NHS written by Bryan Harry and staff at the National Park Service Pacific Islands Support Office in Honolulu.

Pu`uhonua o Hōnaunau National Historical Park

Introduction

Pu`uhonua o Hōnaunau National Historical Park (NHP) is on the western coast of the island of Hawai`i in the South Kona District, approximately 26 km (16 miles) south of the city of *Kailua-Kona.* The Park entrance is on Highway 160, which connects to the *Māmalahoa* Highway upslope of the Park. The Park, approximately 74 ha (182 a) in area, stretches along the coastline from *Hōnaunau* Bay to *Ki`ilae* Bay and includes coastal portions of three *ahupua`a* or Hawaiian land divisions: *Hōnaunau, Kēōkea*, and *Ki`ilae.* There is also a detached parcel of 1.5 ha (3.7 a) upslope of the main Park that contains a dormitory and is the site of the upland or *mauka* garden, also known as "*Kihapai uka*". The climate of this part of the *Kona* coast of Hawai`i is relatively dry and warm and has its greatest rainfall in the summer. Mean annual rainfall at *Hōnaunau* is 650 mm (26 in.) (Giambelluca *et al.* 1986). The Park is on the coastal plain of *Mauna Loa* on prehistoric flows that originated from the summit and southwest rift of the volcano. The lava flows that make up the substrate of most of the Park have been dated at 750 to 1,500 years before present (bp), but the flows in the southern part of the Park belong to an older group of flows dated at 1,500-4,000 years bp (Lockwood and Lipman 1987; Lockwood *et al.* 1988). There is very little soil covering the *pāhoehoe* lava within the Park (Sato *et al.* 1973).

Legal Mandate

Pu`uhonua o Hōnaunau National Historical Park (or PUHO) was named "City of Refuge NHP" when it was authorized in 1955. The authorizing legislation set aside the area of the Park to preserve historic sites and objects of national significance. While no specific time was identified in the enabling legislation, the Park master plan dating from the 1970s specified that the Park should represent the area as it appeared during the

time of the Hawaiians (National Park Service 1996a). As the *Pu`uhonua* was abandoned as a religious site after the breaking of *kapu* and collapse of the Hawaiian religious institution in 1819, the early years of the 1800s are a reasonable target date for interpretation of the features of the Park. The only exception to the early 1800s as a target date is *Ki`ilae* Village, a relatively modern site inhabited until 1926.

Early History and Vegetation

The area that eventually became Pu`uhonua o Hōnaunau NHP includes sites of great religious and cultural significance, and the nearby coastal villages were densely populated with people at the time of European contact and in the late prehistoric period (Greene 1993). After abandonment of the temples and other religious sites, the lands within the Park continued to be inhabited and were used to graze introduced goats and cattle (Emory 1986a; Apple 1965). There is little left of the original vegetation before human inhabitation at any lowland site on Hawai`i Island, but it is assumed from current vegetation structure that the area of the Park would have supported a forest or shrubland vegetation. Open forests of *`ōhi`a lehua* (*Metrosideros polymorpha*) are extant upslope of the Park and on rough lava flows to the south. Other native trees that were likely present in a pre-human vegetation at the lowland site of the Park include *lama* (*Diospyros sandwicensis*), *`ohe makai* (*Reynoldsia sandwicensis*), and *wiliwili* (*Erythrina sandwicensis*) (Smith *et al.* 1986). Based on the findings of pollen analysis at other lowland sites in the Hawaiian Islands (Athens *et al.* 1992), many other species may have been present in the original vegetation of the site that are no longer found nearby; some of the original components of vegetation may be very rare or even extinct. Kirch (1982) summarized the major changes that Hawaiians brought about in the vegetation of the lowland zone of the Hawaiian Islands; almost any area receiving 500 mm (20 in.) of precipitation may be assumed to have been used for some form of agriculture, and burning was a common tool to clear vegetation and promote certain species. Because the landscape that the Park Service would like to recreate is that of the early 1800s, Polynesian introductions, common native plants of the lowlands, and native plants with cultural uses may be assumed to have made up most of the vegetation of the Park during the critical time period. The cultural landscape desired for the southern part of the Park in *Ki`ilae* Village is more flexible, as the historical time period for this site extends from the early 1800s to 1926.

Existing Vegetation

Vegetation within Pu`uhonua o Hōnaunau National Historical Park is almost entirely alien in composition. A vegetation map of the Park produced more than ten years ago recognized 26 different mapping units in four basic categories: strand vegetation, managed woodland of coconut palms (a Polynesian introduction), alien dominated grassland, and mixed shrublands dominated by alien species (Leishmann 1986). A more recent vegetation survey found that most of the Park away from the developed area near the Visitor Center and the coastline was covered by an alien shrubland in which *ēkoa* or *koa haole* (*Leucaena leucocephala*) was the dominant species; the southern third of the Park was vegetated with a tall *ēkoa* shrubland with a ground cover of Guinea grass (*Panicum maximum*) (Pratt and Abbott 1996a). More than 70% (96) of the 134 vascular plants currently found in the Park are alien species, but 23 native species and 15 Polynesian introductions are also present (Pratt and Abbott 1996a). While a few of these native plant species are scattered throughout the Park, most native plants persist on the shoreline, at several brackish pools, or as plantings near the Visitor Center.

Primary Resources and Resource Zones

In a recent project to evaluate the significance of the cultural resources of the Park for management purposes, the entire Park was considered a resource zone in which the management of cultural landscapes is important and related to the significance of the Park (PUHO files). The northwestern corner of the Park within the enclosure of the great Wall of the *Pu`uhonua* was judged to be the resource area in which management of the cultural landscape is of the highest priority. The coastline throughout the Park up to the

1871 Trail, as well as the *Ki`ilae* village site in the south of the Park, were considered to be significant resource areas. The upper half of the Park and the developed area near the Visitor Center were rated as Zone III areas, where the resources are limited or less known or have been impacted by Park development (Fig. 1).

Strategies of Vegetation Management at Pu`uhonua o Hōnaunau NHP

Alien Plant Control

As is true for the two other *Kona* National Historical Parks, the vegetation of Pu`uhonua o Hōnaunau NHP is currently dominated by alien shrubs and grasses, except in areas developed for visitor use. The portion of the Park upslope of the 1871 Trail is covered by a dense shrubland of alien species, the most abundant of which is *ēkoa*. South of the *Alahaka* or *Keanae`e Pali*, the stature of *ēkoa* is tree-like and the ground cover is primarily tall Guinea grass. Along the 1871 Trail, the alien Natal redtop grass (*Melinis repens*) is common, and between the trail and the coastline, vegetation is a mix of alien shrubs and grasses, Polynesian introductions, and a few native plants. The area within and adjacent to the Great Wall of the *Pu`uhonua* supports a beautiful grove of graceful, tall coconut palms or *niu* (*Cocos nucifera*). A number of native and Polynesian tree and shrub species have been planted near the Visitor Center. Brackish ponds near the *Pu`uhonua* support primarily native plants on their shores; the lack of alien plants here is largely due to past alien plant management efforts.

Although the Park is less than 75 ha (185 a) in size, past efforts have not resulted in long-term Park-wide removal of common alien plants. The woody alien species predominating in the shrublands of the Park cannot be killed by simple cutting, but must be treated with an effective herbicide for control to be accomplished. While one shrub is the dominant for vegetation classification purposes, at least five other shrub species are widespread and have significant cover within the Park. At many sites, effective alien plant control involves the treatment of a suite of alien shrub species, as well as removal of a ground cover of alien grasses and herbs (Appendix A). Because of these constraints and the past difficulty of maintaining cleared conditions following removal projects, it is unlikely that the entire Park will be cleared of alien species in the near future. As is true at the two other *Kona* Historical Parks, the logical focus of vegetation management efforts is priority sites within the Park.

Fire is unlikely to be an important management tool for widespread alien plant control in the Park, but fire may have potential as an agent to replace Natal red top grass with native *pili* on an small scale. Fire may also have some value in suppressing encroaching alien shrubs at sites near the coast and the 1871 Trail. Past prescribed fire in the Park showed some promise of alien shrub suppression, but Park staff were unable to maintain the burned area, which the alien *ēkoa* subsequently reinvaded (Jack Minassian, pers. Comm. 1998).

Current vegetation management is the treatment and removal of alien vegetation from the priority sites most often visited, particularly those in the northwestern section of the Park near the *Pu`uhonua* and Visitor Center. The Park has been divided into 11 weed control sectors (Fig. 2), and records are kept on alien vegetation management efforts and amount of herbicide used within these sectors (Victor Bio, PUHO files).

In addition to controlling the worst alien invaders at priority sites, particularly noxious alien plant species should be controlled Park-wide, if possible. Those recent invaders that are still localized in their distribution, but have the potential to become serious pests, should be eliminated from the Park, as soon as possible (Appendix A). Weeds that are a high priority for eradication are buffelgrass (*Cenchrus ciliaris*), prickly pear cactus (*Opuntia ficus-indica*), and date palm (*Phoenix* sp.). Park workers have already initiated eradication efforts on date palm. Other invasive alien plant species have been eliminated from the Park in the last 10 years, and these should not be permitted to re-establish. Fountain grass (*Pennisetum setaceum*) is chief among the pests that Park personnel have successfully eliminated; periodic monitoring of roadsides

and parking areas will be needed to prevent its re-invasion. While several other herbaceous alien plant species have localized distributions within the Park, most of these are relatively innocuous and do not deserve intensive management, except where removal is important for the restoration of the historical/cultural scene.

New alien plant species may be prevented from invading the Park by the periodic monitoring of roads, trails, parking areas, fencelines, dry streambeds, and other likely sites of entry. When a new alien plant is found within the Park, it should first be identified (to confirm its alien status), and then it should be mechanically removed or treated with herbicide. Records of such new invaders should be kept to assist Park managers to evaluate the seriousness of the alien plant threat. These monitoring records should then become part of the permanent Park files.

The Park would benefit from having an Integrated Pest Management (IPM) plan. Among the three *Kona* Parks, only Pu`ukoholā Heiau NHS has such a plan. An IPM plan reviews control methods used for different alien plant pests in the Park (as well as for any insect or rodent pests), and serves as timely documentation of the Park's alien organism control programs. The IPM plan and the current Resources Management Plan should also contain the list of alien plant species that are priorities for control within the Park. Categories of alien plants to be considered in the priority list are species to be controlled only in priority sites, localized alien plants to be eradicated from the Park or controlled Park-wide, highly invasive species to be searched for along roads and points of entry, and ornamental species to be removed from the Park as inappropriate to the historical scene. Innocuous alien species should be ignored, except at sites where they are treated as part of a suite of alien species. Because the most invasive weeds of the Park require herbicides to control infestations, it is particularly important for the Park to retain personnel trained in herbicide use and to provide training to any staff members subsequently hired to carry out vegetation management. Herbicide use is sometimes a controversial subject with the public, so it is critical that Park managers use caution in herbicide application, follow all label instructions, determine the lowest effective rates to use in the Park, and continue to keep accurate records. Wetlands are especially sensitive areas, and extreme caution should be exercised when herbicides are used to manage vegetation near the Park's ponds.

Native Plant Management and Restoration

General strategies for native plant management and restoration. - The entire Pu`uhonua o Hōnaunau National Historical Park falls within an historic zone, with four small areas recognized as Park development subzones to permit the construction of the Visitor Center and parking, a picnic area, administration and maintenance offices, and a sewage treatment plant (National Park Service 1996a). Within Park development zones, Park Service policy mandates that plantings should conform with the surrounding cultural zone landscape and should use native species to the maximum extent possible (National Park Service 1988). Within the historic zone, lands within the *Pu`uhonua* and along the coast are deemed to be of the highest priority for preservation and management. The goals of vegetation management throughout the historic zone are removal of alien plant species interfering with the historic/cultural scene and restoration of native and Polynesian species that best characterize the vegetation of the early historic period. For the purposes of this discussion, Polynesian introductions may be treated as native plants in the Kona Parks. As removal of all alien plant cover throughout the Park is not feasible, the focus of alien plant control and subsequent restoration of natives should be the most significant resource zones and the highest priority historical and cultural sites within the zones. There are 15 sites within the Park recognized independently on the National Register of Historic Places (National Park Service 1976; National Park Service 1994a). All of these are discussed in the following section on priority sites for vegetation management.

Despite the classification of all lands within the Park as an historic zone, several sites also contain features of natural value; most important are the areas surrounding the brackish pools near the Great Wall of the *Pu`uhonua* and the patches of native strand vegetation along the coastline. At several other sites of historical or cultural significance in the Park, there are elements of natural vegetation persisting that should

be recognized as deserving of protection and enhancement. Rarely do the management needs of archaeological features and historical sites conflict with the need to conserve native plants.

Because it is largely covered with alien vegetation, restoration of vegetation depicting the historic scene of the early 1800s is a great challenge. However, past Park management projects made a start at restoration by clearing alien woody vegetation from the northwestern section near the *Pu`uhonua*, as well as from much of the coastline and near-coastal area below the 1871 Trail (National Park Service 1976). While Park staff was not able to maintain open conditions in some of the previously cleared areas, much of the developed and frequently visited portion of the Park has been freed of the "tangle of exotics" noted by botanists in the 1950s (Greenwell 1986).

The restoration of an Hawaiian cultural landscape will involve the protection of existing native and Polynesian plant species, the augmentation of those native species that are currently unnaturally rare, and the introduction or re-introduction of native and Polynesian species that were likely part of the vegetation of *Hōnaunau* during the late prehistoric and early historic period. Criteria for selection of plant species to introduce to the Park for the restoration of the historical scene are: status as native or Polynesian species, appropriateness to lowland and coastal outplanting sites, and ability to enhance the cultural/historic scene. The balance of native to Polynesian species should be determined on a site by site basis. Most Polynesian plant species likely to have been in the area during the historic period are already found within the Park, but may benefit from some augmentation. While crop plants are represented within the Park only by demonstration plantings near the Visitor Center, the addition of such species elsewhere in the Park is probably unnecessary, as agriculture is not an important theme of the Park. It is inappropriate to use alien species as outplantings in the Park, except possibly at *Ki`ilae* Village, where the historic period to be restored is the late 1800s to 1926, the date of abandonment. National Park Service policy permits the deliberate introduction of alien plant species into a cultural zone only in rare cases, and then only if the alien plant may be controlled and maintained by cultivation (National Park Service 1988).

Native species that would have been natural components of the coastal and lowland vegetation of South *Kona* and Polynesian species likely to have been cultivated or growing wild in the vicinity of habitations should be considered for introduction to the Park at priority sites for restoration. A few such species, along with those native and Polynesian plants already in the Park, should provide Park managers with a relatively large number of potential species for outplantings. Native and Polynesian species already in the Park, such as *milo* (*Thespesia populnea*), *hala* (*Pandanus tectorius*), *naupaka kahakai* (*Scaevola sericea*), *noni* (*Morinda citrifolia*), and *kou* (*Cordia subcordata*), will be the most efficient choices for propagation and outplantings, as seeds are readily available and the species are obviously thriving in the local environment. However, other native plants of the lowlands are also likely to grow well within the Park, and seeds of common woody plants are not generally difficult to obtain. See the next section for guidelines to seed collecting. A number of common native trees and shrubs are possible candidates for introduction to the Park, and a few rare species should also be considered for outplanting. To some degree, the upland garden in the detached parcel upslope of the main Park has been used as an outplanting site for native species. In an early Resources Management Plan (National Park Service 1976), the upland garden was recognized as a potential propagation site, and its outplanted natives were considered to be seed sources for future outplantings and for potted plants to be displayed in the Park.

Management strategies for existing native plants. - Only 17% of the Park's flora is native, and another 11% is composed of Polynesian introductions (Pratt and Abbott 1996a). Most of the 23 native species found during the last botanical survey were concentrated in the developed part of the Park near the Visitor Center or were growing near the brackish pools or along the coast. Nine native species were noted in the alien shrub-dominated upland portion of the Park, but these native plants were scattered in very low numbers. Among these native species of the shrubland were the former candidate endangered species *pua pilo* or *maiapilo* (*Capparis sandwichiana*), the uncommon Hawaiian moon flower vine (*Ipomoea tuboides*), and *pili*

grass (*Heteropogon contortus*). The only native plants that may be considered common in the Park are the low-growing shrub *`uhaloa* (*Waltheria indica*), *makaloa* sedge (*Cyperus laevigatus*) of the ponds, and the coastal *naupaka kahakai* and *Fimbristylis cymosa*. A number of native and Polynesian plants have been planted near the Visitor Center, where they may be seen along the trails between the parking lot and the Great Wall.

The past Resources Management Plans for the Park have consistently recognized the need to propagate and reintroduce native plants, but the conservation of existing native plants has not been stressed (National Park Service 1976; National Park Service 1994a); this is perhaps due to the idea that native vegetation is "virtually absent" from the Park (National Park Service 1995). Nonetheless, native plants are well represented in the vegetation of the coast and wetlands, and many native woody plants have been planted in the developed part of the Park. As an overall strategy, existing native plants should be conserved, whether naturally occurring or intentionally planted. Future Park development projects should take the potential presence of native plants into account; all currently proposed building projects have been sited in areas covered by alien plants. If possible, native plants should be spared when trails or archaeological sites are cleared of alien plants. Despite the desire to clean vegetation from sites and leave exposed rock as the predominate ground cover, native plants should not be intentionally targeted for treatment unless they are harming archeological or cultural sites by their presence. When common native plants are growing on archaeological features and are potentially disruptive, they should be removed along with alien plants. Rare or uncommon native plants extant in the Park should not be harmed.

At present, there are no conspicuous out-of-place plantings of native or Polynesian species in the developed part of the Park. Those natives that have been outplanted, such as *`ākia* (*Wikstroemia pulcherrima*), *`a`ali`i* (*Dodonaea viscosa*), and *pōhinahina* (*Vitex rotundifolia*), are lowland or coastal species that were likely present in the area before grazing animals and the invasion of alien woody species greatly altered the vegetation of the *Hōnaunau* area. The Polynesian introductions found near the Visitor Center, for example *kī* or *ti* (*Cordyline fruticosa*), *kamani* (*Calophyllum inophyllum*), and crop plants such as *`uala* or sweet potato (*Ipomoea batatas*) and *wauke* (*Broussonetia papyrifera*), may be considered part of the cultural scene and contribute to the interpretation of the Park. One inappropriate use of a non-Hawaiian (Samoan) cultivar of coconut palm was reported in a project statement of a recent Resources Management Plan (National Park Service 1995). While replenishment of coconuts in the coastal groves of the Park is a ongoing need, obviously non-Hawaiian cultivars, such as the low-stature Samoan type, should not be used to replace dead coconut trees at Pu`uhonua o Hōnaunau NHP. Those few Samoan coconut trees currently growing in the southern part of the Park should be removed. In areas where intensive management of vegetation is planned, a specific site-management plan should be developed to guide the choice of species and varieties to be planted and, in some cases, to indicate individual plants to be removed. Such a site management plan will allow the Park to comply with Park Service directives and guidelines on revegetation, which require written records and accurate maps of revegetation work (National Park Service 1993a).

Monitoring should be part of any outplanting program in the Park, and a few existing native and Polynesian species should also be monitored to determine their status. The brackish ponds support a number of native plant species and are dynamic communities subject to accumulation of sediments and succession of wetland plants. Periodic monitoring of the species composition and cover at several spots on the edge of the larger pools would help Park managers understand trends of succession here. This is particularly important, if vegetation removal projects are carried out in or near pools. Without some form of monitoring, the success of management programs cannot be easily gauged. Coastal strand communities should also be monitored at intervals of several years to assess species composition and cover. Individual native plant species that deserve a basic monitoring program are the rare *pua pilo,* Hawaiian moon flower, and *pili* grass (the naturally occurring patches).

Management strategies for outplantings of native species. - Suggestions for native and Polynesian species to outplant are given in the restoration section of each of the priority sites discussed below. Strategies for outplanting native species in the Park may involve augmentation of the populations of species currently growing in the Park, restoration of native species missing from the Park but documented from the area, or introduction (or re-introduction) of species thought to be appropriate to the near coastal location of the Park. Augmentation and restoration of missing species is straightforward, because there is no need to justify the outplanting of individuals within the Park. Introduction of native or Polynesian plant species should be proposed only there is good reason to suppose that the species may have been present in or near the Park during the prehistoric or early historic period. In general, common native plant species should be the focus of restoration efforts, since they are most likely to survive, and seeds are easier to obtain. Dry forest trees likely to have been a part of the original vegetation of *Hōnaunau* should also be considered for introduction to the Park: *`ōhi`a lehua, lama, `ohe makai, wiliwili, naio* (*Myoporum sandwicense*), and *alahe`e* (*Canthium odoratum* or *Psydrax odorata*).

Rare native plant species appropriate to the coast and dry lowlands may also be considered for restoration of the historic scene. If endangered species are desired for introduction, Park managers should apply to the State of Hawaii (and the U. S. Fish and Wildlife Service, if necessary) for permits to propagate and hold endangered species within the Park. One good candidate for re-introduction to the Park is the endangered *loulu* palm (*Pritchardia affinis*), because there are *loulu* tree molds preserved in lava near the shore (Greenwell 1986). Those endangered species that have already been outplanted in the upland garden (see priority site discussion) should be maintained, and the Park should apply for a State Endangered Species permit to possess these species for educational and interpretive purposes. Since the endangered plant species were derived from previously cultivated material and all were obtained prior to their listing as endangered, a Federal Endangered Species permit is not required (Marie Bruegmann, pers. comm. 1997).

Native species deserving augmentation of their low numbers in the Park are *pua pilo* and Hawaiian moon flower, both known from only one extant individual (Pratt and Abbott 1996a). *Pili* grass, *`ilima* (*Sida fallax*), *`ala`alawainui* (*Peperomia leptostachya*), and the Polynesian *`auhuhu* (*Tephrosia purpurea*) would also benefit from outplanting to increase their numbers in the Park. Missing species that should be restored to the Park are *`ilie`e* (*Plumbago zeylanica*), *kīpūkai* (*Heliotropium curassavicum*), and *kupukupu* (*Nephrolepis exaltata*). All three species have disappeared from the Park between the botanical survey of 1984-86 (Smith *et al.*1986) and that of the early 1990s (Pratt and Abbott 1996a).

Helpful guidelines for outplanting are found in National Park Service directives (National Park Service 1993a), unpublished reports of other Parks (Hawaii Volcanoes NP), and in material developed by other organizations (Woolliams and Llop 1993). Specific seed collection guidelines should be developed along with the outplanting program in the Park. In general, seeds should be obtained from the nearest natural source, to take advantage of possible local site adaptations. Seeds should not be collected far in advance of the time they will be sowed or germinated; long-term seed storage often results in loss of viability (National Park Service 1993a). The source of any seed used in Park outplanting programs should be recorded in permanent Park files. Propagation guidelines should also be developed for the Park outplanting program. Plants should not be purchased from commercial nurseries or private growers without proper documentation of the source of the seed and the propagation techniques used. Likewise, plants without documentation should not be accepted as gifts from private individuals. The Amy Greenwell Ethnobotanical Garden should be considered as a site for propagation of native and Polynesian plants for the Park, using seeds collected by Park personnel or designated collectors with the proper technical expertise to identify plants and properly care for seeds. The Garden has a Memorandum of Understanding with the three *Kona* National Historical Parks to accomplish plant propagation work, but extensive use of the Garden may require a more formal arrangement. Alternatively, the Park could develop its own propagation facilities at the site of the upland garden. Rudimentary capability for propagation and plant production already exists at this detached site.

Material to be outplanted in the Park should be healthy and free of disease or insect pests (National Park Service 1993a). Plants propagated for the Park should be raised in sterile potting medium from which the upper half inch of soil is removed immediately before outplanting. Plants should be decontaminated with acceptable pesticides at least two weeks before outplanting to remove any plant pests, including nematodes and scale insects. Growth and survivorship of outplanted individuals should be monitored periodically. Records of species outplanted, seed sources, treatment regime, and fate of outplanting should be kept within the Park. Periodic reports of plants restored to the Park and outplanting success should be produced to document the Park's outplanting and restoration program. An example of rules for seed collection, propagation, and outplanting is the guideline recently developed and adopted by Resources Managers at Hawaii Volcanoes National Park (Tunison 1996).

Vegetation Management in Priority Sites

The following 12 sites are the highest priorities for vegetation management within the Park; included within these areas are all of the 15 Park sites officially listed on the National Register of Historical Places. All of these 12 priority sites, except the one proposed for new administration and maintenance buildings, are currently receiving some form of vegetation management. Although not stated in Park planning documents, some of these sites are obviously considered to be higher priorities for management than are others. It is clear from current management activites that the *Pu`uhonua*, associated archaeological sites, the Visitor Center, the coastal picnic area, and the current site of administration buildings are the highest priorities for vegetation management. A second tier of priority sites are only partially managed; these are *`Ōma`o Heiau*, *Keawe*'s house complex, the three *hōlua,* the *Alahaka* area, the 1871 Trail, and *Ki`ilae* Village. The site of *Ki`ilae* Village, in particular, is too extensive to be managed in entirety under current funding and staffing levels. The upland garden falls into a category by itself because it is not contiguous with the rest of the Park, and its management is not critical to the operation of the National Historical Park as a whole. The vegetation of the upland garden is only partially managed, but maintenance of the cleared portion of the site is very labor-intensive. It is recommended that Park staff develop a ranking system to prioritize vegetation management at all 12 sites, and add to this list any other sites requiring alien plant control or other intensive management.

Area within the Great Wall of the Pu`uhonua and the Royal Grounds

Description of features and vegetation. - The *Pu`uhonua* at Hōnaunau is one of the most significant archaeological and historic sites in the Hawaiian Islands (Kirch 1985). Although at least ten other sites on Hawai`i Island are thought to have been used as *Pu`uhonua* (Kelly 1986a), the *Pu`uhonua* o Hōnaunau is the best preserved and best known site of its kind. In Hawaiian culture, a *pu`uhonua* was a place of refuge, where *kapu* breakers and those defeated in war or fearful of the destruction accompanying war could escape to safety (Kelly 1986b). Priests associated with the *pu`uhonua* and *heiau* could then perform the necessary rites to absolve the law-breakers and allow them to leave. The complex of features enclosed by the Great Wall at *Hōnaunau* is recognized as the most important area of the Park to protect, manage, and interpret (National Park Service 1976; National Park Service 1996a; Brown 1997).

Four features within the *Pu`uhonua*, including the Great Wall or *Pā Pu`uhonua*, are individually listed as major archaeological features on the National Register of Historic Places (Greene 1993). The *Pu`uhonua* or place of refuge was established before 1600 AD, possibly by the chief *`Ehukaimalino* around 1475 AD (Barrère 1986). The establishment of the *Pu`uhonua* apparently predated the construction of the Great Wall, which has been dated at 1550 AD. The most massive ancient wall in the Hawaiian Islands, the Great Wall stretches for 303 m (1,000 ft), and is approximately 3.6 m (12 ft) high and 5.5 m (18 ft) wide (Greene 1993). *`Āle`ale`a Heiau* and the Old *Heiau*, now enclosed by the wall of the *Pu`uhonua* Fig. 3), were built earlier than the Great Wall; the first of at least seven *`Āle`ale`a* platforms was estimated to date from 1250 AD (Ladd 1985). *`Āle`ale`a Heiau* was restored in 1902 (Stokes 1986a) and was the subject of an archaeological excavation and stabilization in the 1960s (Ladd 1985). Although ancient, this *heiau* remains a well-defined

feature just southwest of the *Hale o Keawe*. By contrast, the Old *Heiau*, southwest of *`Āle`ale`a,* has been reduced to a rough mound of stone by repeated high wave and storm damage following its early abandonment.

The most prominent heiau of the *Pu`uhonua* is the platform supporting the *Hale o Keawe*, built to house the remains of more than 20 deified chiefs of *Kona*; this very important *heiau* was erected for the Chief *Keawe-i-kekahi-ali`i-o-ka-moku* in approximately 1650 AD (Barrère 1986). The heiau was in use until the abolition of the *kapu* in 1819, and the remains of the chiefs were not removed until 1829, at the order of Queen *Ka`ahumanu* (Apple 1966). After the *heiau* ceased to be used for religious purposes, its sacred images and other movable objects were taken (Emory 1986b), and eventually its structures fell into ruin. While the *Hale o Keawe* was noted by travelers passing by *Hōnaunau* as late as 1841, a decade later only the wooden fence was still standing, and by 1900 little of the *heiau* remained visible (Greene 1993). The hard wood of the indigenous *kauila* (*Alphitonia ponderosa*) used for the palisade of the *heiau* (Apple 1966) was responsible for the durability of the fence. Even the rock platforms of the *heiau* were eventually disturbed by high wave action; by the turn of the century 1902, the *Hale of Keawe* ruins were an indefinite "pile of rocks" (Ladd 1985). The platforms of the temple were restored in 1902 at the expense of Bishop Estate Trustees, and a seawall was constructed by the County in 1926.

After the site was acquired by the National Park Service (in 1961) and a historical pre-restoration study was carried out (Apple 1966), the *Hale o Keawe* was excavated and restored in 1966-67 (Ladd 1985). Many of the early European and American visitors to Hawai`i described and pictured the *Hale o Keawe* before it fell into ruin (Emory 1986b). When the Park Service later reconstructed the fence and other temple structures upon the stone *heiau* platform in 1967-68 and again in 1982, restorers were guided by the illustrations of William Ellis (Greene 1993), who was particularly interested in the *Hale o Keawe* as the last standing *heiau* in Hawai`i (Emory 1986b). Today, visitors approach the *Hale o Keawe* (and the Great Wall) from the Visitor Center along trails passing through the Royal Residence grounds. The restored *heiau* platform supports an offering tower, reproductions of sacred images, a wooden palisade, and a prominent thatched *hale* or house that represents the mausoleum of the deified Hawaiian chiefs.

Several other features within the Great Wall are noteworthy. One currently inconspicuous feature adjacent to the *Hale o Keawe* is the *Hale o Puni* or priest's quarters, now reduced to a platform. Another site is the *Hale o Papa*, a stone platform on the south wall of the *Pu`uhonua* that may have been a women's *heiau*. A prominent feature on the interpreted visitor trail, the *Keoua* stone is a rectangular dressed slab on the north side of *`Āle`ale`a Heiau.* Another well-marked stone along the trail is the *Ka`ahumanu* Stone on the southeast corner of *`Āle`ale`a Heiau*, a site where Queen *Ka`ahumanu* is said to have hidden after fleeing from *Kamehameha* I. Although they are currently unmarked, earlier maps show graves near the Old *Heiau* and near the southern arm of the Great Wall. Small features of the enclosure include *papamū* pecked into smooth rock for the playing of the game *kōnane,* and at least one conspicuous petroglyph. A brackish water pool, named *Makaloa* on some maps, covers a large area adjacent to the eastern arm of the Great Wall. Many of these important features would not be visible without past and current vegetation management efforts.

The Royal Grounds, also known as the Palace Grounds or Royal Courtyard, were originally the site of chiefly residences. The *Keone`ele`ele* inlet was restricted to the *ali`i*, and common people could not land on the shore or walk through the Royal Grounds (Emory 1986b). When Stokes surveyed the area in 1919, little evidence of past chiefly inhabitation was noted, other than several platforms and cup marks in the ground to support boundary markers (Stokes 1986b). As remains of royal residences are very rare in the Hawaiian Islands, the Park Service has recognized the importance of this site for protection, interpretation, and eventual archaeological study (National Park Service 1994a). The site of the original Royal Grounds is the area between the modern Visitor Center and the Great Wall and is traversed by a looping visitor trail to the *Pu`uhonua* enclosure. Several reconstructions illustrating traditional Hawaiian buildings are found here,

including a canoe shed. In addition to a large grove of coconuts, a number of trees and shrubs have been planted in this area, but the ground is sandy and largely clear of plants other than the native sedge *Fimbristylis cymosa* and alien grasses, mostly Bermuda grass (*Cynodon dactylon*) and St. Augustine grass (*Stenotaphrum secondatum*). A modern sewage lift station currently located within the Royal Grounds is scheduled for eventual removal to a less conspicuous and less culturally important site (National Park Service 1996a).

Several ponds persist within the area of the original Royal Grounds; collectively called *Hele`ipalala* Ponds, they were apparently used as fish ponds to supply the king (Stokes 1986b). The northernmost of these has been highly modified and supports virtually no vegetation. To the south is a large irregular pond complex adjacent to the Great Wall, which separates the outer pond from the *Makaloa* Pond within the *Pu`uhonua* enclosure (Fig. 3). The vegetation of the southern pool is composed primarily of native or Polynesian plants. A dense stand of indigenous *milo* persists on the southern edge of the pond, and low growing *`ākulikuli* (*Sesuvium portulacastrum*) and beach morning glory or *pōhuehue* (*Ipomoea pes-caprae* subsp. *brasiliensis*), as well as the sedges *makaloa* and *`ahu`awa* (*Mariscus javanicus*) are common in and around the pond. Scattered coconut palms, *noni*, and *kī* plants grow in the area between the ponds and the Great Wall. The only conspicuous alien plants persisting near the ponds are Bermuda grass and scattered young *`opiuma* trees (*Pithecellobium dulce*). Similar vegetation surrounds the *Makaloa* pond within the *Pu`uhonua*, and as the name implies, *makaloa* sedge is abundant within the pond and in an adjacent depression. The depression may represent a filled-in former pool.

The area within the Great Wall currently supports a grove of coconut trees and a few scattered native shrubs; except for sedges in and near the *Makaloa* pool, the low spreading shrub *`uhaloa* and the compact sedge *Fimbristylis cymosa* are the only common native plants within the wall. Scattered alien shrubs within the wall include *`opiuma, ēkoa*, senna (*Senna* spp.), Christmas berry (*Schinus terebinthifolius*), and lantana (*Lantana camara*). Grasses are rare here, but low-growing clumps of Natal redtop grow in the southeastern corner of the Great Wall. Several alien herbs occur with very low cover here; most often seen are spurges (*Chamaesyce hirta* and *C. hypericifolia*), pigweed (*Portulaca oleracea*), blue-seeded portulaca (*P. pilosa*), amaranthus (*Amaranthus* sp.), wild spider flower (*Cleome gynandra*), and *Boerhavia coccinea*.

Current or past vegetation management at site. - After its abandonment as an important religious site, part of the *Pu`uhonua* enclosure was used as a goat pen (Emory 1986a), and the Royal Grounds were divided into walled lots (Stokes 1986b). During the period that the area was used for grazing goats and cattle in the 1800s (Apple 1965), alien shrubs introduced to provide forage for stock animals, such as *ēkoa* and *kiawe* (*Prosopis pallida*), became well established. By the 1950s, the vegetation of *Hōnaunau* was described as "monotonous, thorny, and introduced" (Greenwell 1986). While in use as a County park, some of the *Pu`uhonua* and vicinity was undoubtedly kept clear of vegetation, and later survey and restoration projects required the removal of vegetation from specific sites. After acquisition as a National Historical Park in 1961, the *Pu`uhonua* area was a priority for management, and much of the area *makai* of the 1871 Trail was cleared of alien shrubs (National Park Service 1976). The *Pu`uhonua*, Royal Grounds, and vicinity of the Visitor Center remain the highest priorities for vegetation management and interpretation in the Park (National Park Service 1994a; Brown 1997), and invading alien plants are periodically controlled. The trails connecting the Visitor Center to the important archaeological features of the *Pu`uhonua* are kept clear of all vegetation, both native and alien. Likewise, the *heiau* platforms are periodically treated to remove all vegetation that would cause deterioration or damage to these significant features. Overall, management of alien vegetation in this developed and heavily-visited portion of the Park currently requires approximately 14 days/year for herbicide treatment and at least an equivalent amount of staff time for manual weed control (PUHO files). The herbicide Roundup is used to achieve open conditions and bare *pāhoehoe* or sand substrate. Additionally, volunteer and student groups of 5-10 are used to help maintain this area; in a typical year such groups may devote a month of time to manually remove alien plants (Victor Bio, pers. comm. 1997).

Vegetation management needed to achieve desired condition.- The overall goal of restoration of the cultural landscape within the *Pu`uhonua* and near the Great wall within the Royal Grounds is to maintain open conditions representative of the time the temples were in use and the Royal Grounds were occupied by the *ali`i*. To accomplish this, invading alien species must be periodically controlled, and occasionally native or Polynesian species encroaching on cultural features must also be removed. The coconut grove, a feature present in the earliest illustrations of the area (Greene 1993), must also be maintained. Some native and Polynesian species that probably occurred in the vicinity of the Royal Grounds should be maintained if present and restored if lacking (*e.g. hala, milo, naupaka kahakai, kou,* and *`auhuhu*). The predominantly native and Polynesian vegetation near the brackish ponds should be retained, but some management of native vegetation may be required to prevent the ponds from filling in or decreasing in size. Because ponds and wetlands require special management, a separate site management plan should be developed for the ponds. As at Kaloko-Honokōhau NHP, strategies must be developed to either allow the ponds to age naturally or to arrest succession at an earlier stage. A vegetative screen is desired to block traffic along the road accessing the picnic area and temporary buildings south of the *Pu`uhonua.*

There are references in Park Service documents to the area near the *Pu`uhonua* being bare, sparsely vegetated, or totally modified by Hawaiians (National Park Service 1976, 1994a, 1996a). As the area within the Great Wall would have received heavy human use, it is likely that vegetative ground cover would be minimal. However, early accounts and illustrations dating from the 1820s do not give much guidance (Greene 1993). Invariably, it is the *Hale o Keawe* that is illustrated, and it is represented as framed by coconut palms with a few other unrecognizable woody plants. The botanist James Macrae, who visited the *Pu`uhonua* in 1825, mentioned only coconut palms in his description of the *heiau* or *"morai."* Upon leaving the *Pu`uhonua* and traveling along the coast, he encountered a yellow hibiscus, "euphorbias, convolvuluses, sidas, and diadelphas plants" (Macrae 1972). Except for the "diadelphas", which is a genus currently unknown in Hawai`i, these plants likely represent native species such as *hau* (*Hibiscus tiliaceus*), *`akoko* (*Chamaesyce* sp.), beach morning glory , and *`ilima;* the latter two persist in the Park today.

Early photographs are also of limited use in determining the appearance of the area near the *Pu`uhonua* in the early historic period. While several photographs of *Hōnaunau* from the 1880s and early decades of the 20th century exist in archives and have been recently reproduced in cultural histories of the Park (Bryan and Emory 1986; Greene 1993), the time period of such photographs follows nearly 100 years of grazing by goats and possibly cattle. One photograph of the interior of the *Pu`uhonua* in 1890 shows scattered palm trees and tufts of sedges, but no shrubs or obvious grasses (Greene 1993). A photograph taken by Brigham in 1889 and reproduced in Stokes (1986a) shows the exterior of the Great Wall with no woody vegetation obscuring the rock work, but with low growing sedges scattered over the *pāhoehoe* substrate. A similar photo taken in 1919 shows virtually the same vegetation, and a photograph of the interior of the wall also dating from 1919 reveals a growth of sedges and a few scattered low flowering plants that may be Madagascar periwinkle (*Catharanthus roseus*), a species introduced in the 1880s (Degener 1946-57). The focus of vegetation management within the Great Wall should be the removal of alien shrubs, grasses, and obtrusive herbaceous plants and the tolerance of low-growing native sedges and *`uhaloa*, except where removal is necessary to prevent damage to archaeological features, allow a clear view of the Great Wall, and provide an open path for visitors.

The ponds both inside and outside the Great Wall require the periodic removal of invading alien woody vegetation, and the treatment of patches of alien Bermuda grass may also be desired. Spot removal of native plants to maintain open water areas within the ponds may also be needed periodically. It is likely that the native *makaloa* and *`ahu`awa* sedges would have been subject to harvest for cultural uses during the early historic period. The dense stand of *milo* on the southern edge of the larger of the two exterior ponds should be allowed to remain as a screen between the Royal Grounds and the access road, but encroaching individual *milo* trees will have to be periodically removed to prevent the further extension of woody vegetation into the

pond. Other native and Polynesian plants should be allowed to persist unless they compromise the continued existence of the ponds or obscure the Great Wall or other features.

Recommendations (not in priority order):

- Continue to remove alien woody and herbaceous vegetation from the *Pu`uhonua* enclosure and the Royal Grounds by treating with Roundup or by manual uprooting where possible. If larger alien woody plants must be killed, use the approved treatment of Garlon as a cut-stump method and remove the slash.
- Continue to remove all encroaching vegetation from archaeological features within the *Pu`uhonua* and along visitor paths in the enclosure and on the Royal Grounds.
- If vegetation (either alien or native) must be removed from the ponds, use only herbicides intended for use in wetlands. Prevent ponds from being filled in with vegetation, but tolerate native plants, as much as possible.
- Maintain relatively tall *milo* trees at the edge of the ponds within the Royal Grounds to act as a screen between visitor trails and the access road that passes near the Great Wall.
- Experiment with the use of spot burning to control the herbicide-resistant Bermuda grass near the exterior ponds.
- Remove several *noni* trees and patches of *`ahu`awa* obscuring both the interior and the exterior of the Great Wall.
- Maintain existing native and Polynesian plants within the Royal Grounds.

Restoration of native or Polynesian plants. - The only prominent plantings within the *Pu`uhonua* west of the Great Wall are coconut palms. Palm groves, both within the walled enclosure and within the Royal Grounds, are the result of intentional plantings. One historical palm planting took place in 1867, when Princess Bernice *Pauahi* Bishop planted coconuts as part of a ceremony transferring ownership of the land to her (Stokes 1986b). Palms were also planted in 1908, and the park has continued to replace dying or decadent palms with young ones (National Park Service 1976). Diseased palms should be removed as soon as noted, so as not to spread disease to healthy palms. If coconut disease becomes widespread in the Park, a plant pathologist or agricultural agent should be consulted for advice. No other plantings are found within the Great Wall, and none is needed to restore the cultural landscape of this important area.

By contrast, a number of plants, both native and alien, have been planted (or in some cases volunteered) within the Royal Grounds, between the Visitor Center and the Great Wall. *Hala*, *`a`ali`i, `ākia,* and *milo* are native plants that likely occurred in this area in the past. Polynesian introductions, such as coconut palm, *kukui* (*Aleurites moluccana*), *noni*, and *kī*, are also species appropriate to coastal lowland sites near Hawaiian habitations. Several past outplantings that are out of context in this area include Madagascar olive (*Noronhia emarginata*), pīkake (*Jasminum sambac*), sea grape (*Cocoloba uvifera*), and *pua kenikeni* (*Fagraea berteriana*). As all of these species are relatively recent introductions to Hawai`i from other tropical lands (Nagata 1985; Neal 1965), they do not contribute to the cultural landscape reflecting the early 1800s. Several of these past plantings of non-native trees and shrubs have already disappeared from the Park (Pratt and Abbott 1996a) since an earlier survey in the mid-1980s (Smith *et al.* 1986), and none of them requires immediate action to prevent spreading. Calabash tree (*Crescentia cujete*) and sea island cotton (*Gossypium barbadense*), which were introduced to Hawai`i before 1825, are such early introductions that they do not detract from the Park's attempt to recreate an historical scene.

Recommendations:

- Replace dead or dying palm trees with young coconut palms as needed to maintain the historical groves.
- Remove some inappropriate plantings or allow them to die without replacement. Plantings that do not contribute to the restoration of the historical and cultural landscape include Madagascar olive, *pua kenikeni*, and sea grape.

- Replace or augment native and Polynesian plants in the Royal Grounds and vicinity of the Visitor Center as needed to maintain a landscape similar to its former appearance in the early 1800s. Examples of these are *hala*, *noni*, *kī*, *naupaka*, *`ākia*, and *`a`ali`i*.
- Additional plantings that would enhance the interpretation of the Royal Grounds and area near the Visitor Center should be restored to the site, after confirmation that no archaeological resources will be harmed. Possibilities include *`auhuhu* or fish poison plant, *loulu*, and *pua pilo*, all of which occur elsewhere in the Park.
- Do not outplant within the Great Wall enclosure, where open conditions are desired.

Visitor Center and Parking Lot

Description of features and vegetation. - The Visitor Center, the only permanent modern facility within the Park, consists of a visitor contact desk, small office space not open to the public, a display area, restrooms, and an open air auditorium. The site for the Visitor Center was likely chosen because there were few obvious archaeological or historic features in the area, other than walled enclosures (Bryan and Emory 1986). There are numerous landscaping plantings both in front of the center toward the parking lot and behind the building facing the *Pu`uhonua*. Between the parking area and the main building and in the area adjacent to the auditorium are a number of plantings of food plants and other useful Polynesian introductions, including *kalo* or *taro* (*Calocasia esculenta*), *pia* (*Tacca leontopetaloides*), *mai`a* or banana (*Musa* sp.), *`uala* or sweet potato, *kō* or sugar cane (*Saccharum officinarum*), *wauke*, and *kī*. A few large trees are also found in this area; the largest are alien monkeypod trees (*Samanea saman*) and Polynesian coconut palms. Small and medium-size trees planted here include *kukui* and *kou*. Planters near the auditorium support the native shrubs *naupaka kahakai* and *pōhinahina* or beach vitex.

The paved parking lot adjacent to the Visitor Center has a large vegetated island separating the two halves of the lot, and the small round end of the island nearest the Visitor Center is separated from the larger vegetated area by a paved walkway (Fig. 3). The large island supports planted individuals of coconut, *noni*, *kamani* and *loulu* palms, and has been sown with *pili* grass. The grass is particularly dense in the area adjacent to the Visitor Center. A number of weedy herbaceous species have also invaded the island and are particularly conspicuous at the northern end of the parking lot near the entrance booth. The most common alien species here are Natal redtop grass, scarlet-fruited passion flower (*Passiflora foetida*), blue-seeded portulaca, hairy spurge, Flora's paintbrush (*Emilia* sp.), and coat buttons (*Tridax procumbens*).

Current or past vegetation management at site. - Past management has included the large-scale removal of alien shrubby vegetation and replacement with landscaped plantings of Polynesian and native species near the Visitor Center and parking lot. Current vegetation management involves the periodic treatment of invasive aliens (primarily with the herbicide Roundup) around the Visitor Center and in the parking lot islands and area surrounding the lot. Maintenance of this site and prevention of alien plant re-establishment using herbicides requires approximately 9 work days per year and approximately the same amount of time for manual weed removal (PUHO files; Victor Bio, pers. comm. 1997). When large *kiawe* (*Prosopis pallida*) and monkeypod trees blow down near Park Headquarters, Resources Management staff workers do not plan to replace them (Gordon Joyce, pers. comm. 1997). In this way, there will be some natural attrition of alien tree cover at sites other than those actively managed to control alien plants.

Vegetation management needed to achieve desired condition.- The current level of vegetation management is sufficient to prevent re-establishment of alien shrubs and to maintain the plantings around the visitor center. The parking lot islands require some additional work to maintain the stands of *pili* grass as an attractive ground cover. Burning has been suggested as a management tool to remove alien species and maintain the fire-tolerant grass in the parking lot islands. An experimental prescribed fire was carried out in January 1998 by the Hawaii Volcanoes NP fire management officer and crew after all permits were obtained. Six transects were placed across the islands to provide a pre-fire analysis of the ground cover of the site; this

data set will permit an evaluation of the burning technique in restoration and maintenance of a vigorous cover of *pili* grass. (See later section on Research and Monitoring).

Recommendations:

- Continue to treat and remove alien plants in the vicinity of the Visitor Center and the parking lot.
- Monitor vegetation in the experimental burn site in the parking lot islands and re-evaluate *pili* cover two weeks after burn and at six month intervals for a year.
- If prescribed fire does not achieve desired results of dense pili grass cover in the parking lot islands, mow and resow portions of island where native grass is desired.

Restoration of native or Polynesian plants.- More than ten species of Polynesian introductions have been planted near the Visitor Center and auditorium. These plantings are used to interpret the food plants and other species important in Hawaiian material culture. While most of the culturally important plant species are already present here, the Park staff may determine a need for additional plantings of similar species in this area. Several Polynesian tree species and six individuals of an endangered *loulu* palm have been planted adjacent to the parking lot. Ground cover in the parking lot islands is dominated by *pili* grass, which makes up 64%of the cover in the southern half of the large island and 59% of the ground cover in the small island adjacent to the Visitor Center. While the grass naturally occurs within the Park, *pili* was artificially sown into this area. If a dense cover of *pili* grass is to be maintained, the islands will need to be periodically mowed and resowed. In some portions of the island, where *pili* grass cover is sparse, Park staff intend to remove the grass and replace it with plantings of the prostrate beach form of *`ilima*, a native shrub with bright orange-yellow flowers. The purpose of these proposed ornamental plantings is to provide the visitor with a visually pleasing entry into the Park, while still using native species in landscaping.

Recommendations:

- Maintain existing plantings of Polynesian plants, and replace or add to plantings of useful Polynesian and native plants as needed for interpretive displays at the Visitor Center.
- Remove sparse cover of *pili* in some sections of parking lot islands and replace with plantings of low-growing native *`ilima*.
- Resow *pili* grass and manage as needed to maintain a dense cover of grass in the parking lot islands.
- Care for *loulu* palms planted in the parking lot island to prevent decline or loss of these examples of an endangered species.

Temporary Park Offices and Former Superintendent's House

Description of features and vegetation. - Several temporary buildings are currently being used for administrative offices, maintenance sheds, and equipment storage. These buildings, adjacent to the site of the former Superintendent's house (unoccupied in 1996), are scheduled to be removed after a new administration building and a second maintenance building are constructed elsewhere in the Park (National Park Service 1996a). Because these temporary Park buildings were constructed many years ago in a "significant resource area" in which the Park's goal is preservation of a cultural landscape (Fig. 3), the Park Service has identified the removal of the buildings and the restoration of the site as a priority in plans dating from 1977 (National Park Service 1996a). One old house site is known from beneath the former Superintendent's house, and a number of house sites pens, walls, and tombs are known from the vicinity of the temporary buildings (Emory 1986c). One of the current administration buildings covers the "Thompson House Site," one of the features listed on the National Register of Historic Places (Greene 1993). The former Superintendent's house was demolished in November, 1997, and the construction materials were removed from the Park. At least one of the proposed new buildings to replace the current administration offices may

become a reality in the near future (Geraldine Bell, pers. comm. 1997), at a different Park site with fewer important resources.

The vegetation in the immediate area of the current Park administrative offices is composed of a mix of alien and Polynesian plants, with a few natives planted near buildings. The vegetation of this disturbed area was mapped by Leishmann (1986) as a mosaic of different vegetation types, including coconut grove, *kiawe* patches, mixed exotics, and open *ēkoa* shrubland, plus barren land probably representing the current road and parking area. The yard surrounding the site of the former Superintendent's house supports a number of planted ornamentals, as well as several large *kiawe* trees, a large tamarind (*Tamarindus indicus*), a *loulu* palm, and planted native *hala* trees. The tamarind and *loulu* predate the house, as they may be seen in old photographs of the area (Greene 1993). The front yard contains a small lawn of Bermuda grass. The planted ornamental species (presumably planted in the last 20 years) include bougainvillea (*Bougainvillea spectabilis*), money tree (*Pleomele marginata*), pothos (*Epipremnum pinnatum)*, citrus (*Citrus* sp.), bowstring hemp (*Sansevieria trifasciata*), oyster plant (*Tradescantia spathacea*), hibiscus (*Hibiscus sp.*), Barbados lily (*Hippeastrum puniceum*), jade tree (*Crassula sp.*), baby sun rose (*Aptenia cordifolia*), *Agave attenuata*, and a wide variety of succulents forming large patches of ground cover in the back yard.

Current or past vegetation management at site.- Past management of the area surrounding the administration buildings involved clearing and some planting of natives and aliens; the relatively open conditions immediately adjacent to the structures have been maintained by the use of herbicides and manual removal of alien plants. Approximately 5-6 days/year are required to treat alien vegetation near the temporary buildings and in the vicinity of the administration area (PUHO files), and manual removal of alien vegetation takes at least another 5 days/year (Victor Bio, pers. comm. 1997). Vegetation surrounding the former Superintendent's house was managed as a yard and garden for more than two decades. At least 20 alien ornamental plants that had been introduced to the yard surrounding the house persisted in 1997, but many of these were destroyed or removed in 1998 following the demolition of the house.

Vegetation management needed to achieve desired condition.- The Development Concept Plan (DCP) for Pu`uhonua o Hōnaunau NHP states that when new administration and maintenance buildings are constructed elsewhere in the Park, the existing temporary structures will be removed, and "Following removal, the topography would be restored. Cultural features disturbed by the removal of the structures would be stabilized (National Park Service 1996a)." The plan proposes the manual removal of alien plants and the outplanting of selected native and Polynesian plants.

After the buildings are removed, the site will require at least the same level of alien plant management (*i.e.* 5-6 days) that it currently receives. This management will involve the use of herbicides to control alien shrubs and grasses that will re-invade the site when the human use pattern is altered. The species most likely to become problems here are *ēkoa*, Natal redtop grass, wild spider flower, and scarlet-fruited passion flower; these species are all abundant in the area just mauka of the stone wall behind the temporary buildings and the old Superintendent's house site. Since the Superintendent's house has been removed, an effort should be made to remove the remaining alien ornamental plantings. Most of the alien shrubs, such as money tree and panax (*Polyscias* sp.), can be cut and removed without the use of herbicides. The large array of succulents will be harder to remove. While manual uprooting of these succulent ornamentals may be sufficient to eventually kill them, care will have to be taken to haul away all cut and uprooted material to prevent re-rooting. Under no circumstances should the slash be piled at another site within the Park, as this would only transfer the alien plants from one site to another. The few native plants that have been planted near the site of the former Superintendent's house (*kī*, *hala*, and *loulu*) should be allowed to remain, as they are likely former elements of the cultural landscape. The large, old tamarind should also be left in place, as it is part of the historic landscape. The plumeria (*Plumeria rubra*) planting in this area postdates the time of the desired cultural landscape, as the species was introduced to Hawai`i around 1870 (Degener 1946-57);

it may be desirable to remove plumeria here, while leaving trees in place near *Ki`ilae,* where they have been planted near an historical tomb.

Recommendations:

- Continue alien plant control in the vicinity of temporary Park administration and maintenance buildings.
- Remove remaining ornamental plantings of alien species at the site of the former Superintendent's house, using manual and chemical methods.
- Retain existing plantings of native and Polynesian species appropriate to the area.

Restoration of native or Polynesian plants.- The outplanting of selected native and Polynesian plants is suggested by the Park Development Concept Plan (National Park Service 1996a); species proposed for outplanting include *pua kala* (*Argemone glauca*), *noni*, *milo*, *kou*, *kamani*, and *naupaka kahakai.* While any of these species are appropriate for a restored cultural scene where the current Park administrative buildings are to be removed, *kamani* may be too large a tree to put into an area with significant archaeological resources, and *milo* is unlikely to grow here without irrigation. *Kou* and *noni*, both Polynesian plants, are good choices for the area; both are already present nearby and will likely grow without intensive care. The native *pua kala* is also present behind the existing buildings and could be outplanted at more sites. *Naupaka* shrubs are currently growing *makai* of the road near the shore, and this species would likely thrive if planted where the buildings are to be removed. The plantings of natives already present near the temporary buildings should be allowed to remain; these include *`a`ali`i* and *hala.*

Recommendations:

- Retain existing plantings of native and Polynesian plants appropriate to the area.
- Plant additional native and Polynesian species to restore the area after removal of temporary buildings.

Site of Proposed New Administration and Maintenance Buildings

Description of features and vegetation. - The recent Development Concept Plan (National Park Service 1996a) proposed the removal of existing administration and maintenance buildings and their replacement with two new structures in the *mauka* section of the Park. While the administration building will likely become a reality in the near future (Geraldine Bell, pers. comm. 1997), the proposed maintenance building is not currently a high priority (Gordon Joyce, pers. comm. 1997). The site selected for both new structures is near the existing sewage treatment plant and is reached by an old paved road leaving the access road just outside the Park boundary. This proposed construction site was found to have very few archaeological features in an earlier survey (Emory 1986c); several pens and graves and one ancient trail were the most significant features mapped. The vegetation in the vicinity of the existing sewage plant is *ēkoa* shrubland with Guinea grass and mixed alien herbs. Other than the ubiquitous *`uhaloa*, the only native plant noted near this area on a recent survey was Hawaiian moon flower, and it was located to the south of the proposed development. *Noni* and *`auhuhu* may occur near the new building site, but the loss of a few plants will not impact their populations in the Park.

Current or past vegetation management at site. - There is no current management of vegetation at this site other than what is needed to keep the road and sewage treatment plant clear. The nearby boundary fenceline is also kept clear of alien vegetation as a fuel break and for maintenance of the fence.

Vegetation management needed to achieve desired condition. - During site preparation and construction of the new buildings, alien vegetation will certainly be reduced. After completion of the building project, some level of vegetation management will be required to keep alien shrubs and grasses from re-invading the disturbed land around the new buildings. This will be a recurring management project, but to

some degree, the amount of yearly effort will be reduced by outplanting low-maintenance landscaping plants. Care should be taken to monitor the construction site and examine heavy equipment to prevent the introduction to the Park of new alien plant species. It is particularly important not to re-introduce fountain grass now that it has been successfully eradicated from the Park.

Recommendations:

- □ Continue to manage alien vegetation on the access road, along the Park boundary fence, and at the sewage treatment plant.
- □ Prevent introduction of new alien plant species on heavy equipment used to construct new buildings.
- □ Control alien vegetation in the vicinity of newly constructed buildings.

Restoration of native or Polynesian plants. - After construction of the administration and maintenance buildings, attractive native or Polynesian plant species will be needed for a low level of landscaping around the new structures. The Development Concept Plan (National Park Service 1996a) states that native species will be utilized for landscaping as much as possible. Likely candidates for landscape plants include the herbaceous *pua kala* and the shrubs *kī*, *`a`ali`i*, and *naupaka kahakai*. These plants are attractive, hardy, and require little care (Bornhorst 1996). If the landscape plan calls for trees, possible choices include coconut palm, *hala*, *kou*, and *noni*.

Recommendation:

- □ Landscape new buildings with appropriate native and Polynesian plant species, including *kī*, *noni*, *kou*, *naupaka kahakai*, *`a`ali`i*, *pua kala*, and *hala*. Plant coconut palms only if there is no concern about tall trees exceeding the height of the building and breaking up the roofline.

Picnic Area and Sand Berm

Description of features and vegetation. - The area *makai* of the unpaved access road and the temporary administration and maintenance buildings is currently used as a picnic ground. There has been no development here, other than the placement of a few picnic tables. There are no immediate or long-term plans to expand this picnic area (National Park Service 1996a). The vegetation here consists of an open grove of coconuts and a few large *kiawe* trees. Along the sandy berm on the ocean side of the picnic tables, vegetation cover is mostly *naupaka kahakai* and scattered alien herbaceous plants. The narrow coastal strip of *naupaka kahakai* extends north to the Great Wall, and a few scattered shrubs are found beyond the wall in the *Pu`uhonua* enclosure; *naupaka* also grows along the coast south to the *Keawe* House site. The native sedge *Fimbristylis cymosa* is the primary vegetation of the rocky flats *makai* of the sandy berm along much of the Park's shoreline.

Current or past vegetation management at site. - This site was one of the areas cleared of alien shrubs in the early years of the National Park Service's management of the new Park (National Park Service 1976). Nearby coastal sites were also cleared of alien woody vegetation during excavation and mapping (Soehren and Tuohy 1987). Current control of alien plants in this open and nearly weed-free area appears to require very little effort and is part of the maintenance of the existing administration and maintenance buildings.

Vegetation management needed to achieve desired condition. - The current level of vegetation management is probably sufficient to maintain the picnic area in the desired condition. If it is eventually decided to remove the alien *kiawe* trees here, native or Polynesian trees should be planted first to provide shade necessary to create a comfortable picnic area.

Recommendation:

- Continue to practice low-level control of alien plant species in picnic area.

Restoration of native or Polynesian plants. - If the existing coconut grove is to be maintained, old and dying trees must be periodically replaced with new sprouted coconuts or young plants. This procedure has been followed elsewhere within the Park where the maintenance of coconut groves is desirable (National Park Service 1976). The Park has experienced some loss of sand from the coastal berm during high surf and storms; this erosion results in the exposure and disturbance of archaeological features on the beach, including old burials (Gordon Joyce, pers. comm. 1996). Outplanting of the native beach shrub *naupaka kahakai* and *pōhuehue* or beach morning glory vine should be tried to provide natural vegetation to hold the sand berm in place and reduce erosion and sand loss. Seed sources for propagation material are available within the Park. Soil from outside the Park or unsterilized soil amendments should not be used here (or elsewhere in the Park). The Park (along with the other two *Kona* National Historical Parks) has a Memorandum of Understanding with Amy Greenwell Ethnobotanical Garden in Captain Cook, and the garden has the staff and greenhouse to undertake propagation of native plants for specific outplanting projects in the Park.

Recommendations:

- Continue to replace coconut palms with young plants as old trees die.
- Outplant native beach plants, such as *naupaka kahakai* and beach morning glory on the sandy berm to reduce erosion.

`Ōma`o Heiau

Description of features and vegetation. - *`Ōma`o Heiau* is in a highly visible location just makai of 1871 Trail approximately halfway between the *Pu`uhonua* wall and the *Alahaka* Ramp (Fig. 1). This is the first of two prominent *heiau* near the trail in *Kēōkea `ahupua`a.* Emory in 1957 was also given the name *Ma`o* for the *heiau*. The heiau was considered "remarkable" for its use of a natural column of lava in the place of a constructed oracle tower or *lananu`u* (Emory 1986c). *`Ōma`o Heiau* was cleared and mapped in 1985 by National Park Service archaeologists; they noted seven prominent surface features on the *heiau* and recognized possible burial mounds as Emory had suggested earlier (Somers 1986). The *heiau* was not stabilized during the recent work, because the walls had fallen to a point that stabilized them naturally.

Existing vegetation on and immediately adjacent to the *heiau* is relatively open, as the site has been cleared of woody vegetation several times in the recent past. The surrounding area is dominated by Natal redtop grass with scattered *ēkoa* shrubs. Farther away from the *heiau, ēkoa, klu* (*Acacia farnesiana*), and *`opiuma* grow in a dense alien shrubland (Pratt and Abbott 1996a).

Current or past vegetation management at site. - As *`Ōma`o Heiau* is *makai* of the 1871 Trail, it may be part of the 18 ha (45 a) cleared of alien vegetation soon after the Park was acquired by the Service (National Park Service 1976). Clearing was undertaken more than 10 years ago when survey and mapping of the feature was accomplished (Somers 1986). Recently, Park workers have cleared the surface of the *heiau* and the immediate area between the *heiau* and the trail; shrubs were cut and painted with the herbicide Garlon, and grasses and herbaceous plants were sprayed with Roundup. The initial effort required 20 person days (4 people for 5 days) (Victor Bio, pers. comm. 1996), and maintenance of the site takes approximately 8 partial days/years devoted to this section of the Park (PUHO files).

Vegetation management needed to achieve desired condition. - The desired condition is for the surface of *`Ōma`o Heiau* to be clear of alien plants and for an unvegetated space to be maintained around the *heiau* walls and between the *heiau* and the 1871 Trail. The proximity of this large *heiau* to the Visitor Center and the main trail traversing the Park makes it an excellent site to interpret. Somers (1986) noted that the only stabilization the *heiau* needed was the continued removal of vegetation. Regrowth of alien shrubs

on a cleared archaeological feature is potentially damaging to its integrity and may interfere with its preservation. It may be best to leave sites covered with vegetation rather than clear them and allow regrowth repeatedly.

Recommendation:

- Maintain open conditions on *`Ōma`o Heiau* and in an area between the *heiau* and the 1871 Trail; continue to spray alien plants at least annually to prevent reinvasion of weeds.

Restoration of native or Polynesian plants. - No species are recommended for planting at this site.

Keawe's House Complex and Nearby Historical Features

Description of features and vegetation. - The Chief's residence on the coast in *Kēōkea ahupua`a* is composed of a large multi-sectioned platform surrounded by a wall. According to Emory (1986c), this is the house site of King *Keawe*, possibly the *Keawe* who was the great grandfather of King *Kamehameha* I, and therefore the site is of great historical and cultural significance (Greene 1993; Barrère 1986). Emory also evaluated the well-preserved complex as an excellent example of a chiefly residence containing three important houses: the *hale mua* or men's house, the *hale `āina* or women's house, and the *hale noa* or sleeping house. Two fishing shrines are found nearby, closer to the shore. A recent Pu`uhonua o Hōnaunau Resources Management Plan stated that walls and platforms of the house complex have been knocked down by domestic animals and by fishermen (National Park Service 1994), but the feature appeared to be in relatively good condition in 1997. This complex is adjacent to a jeep road currently used for foot traffic. Located on the shore at the point where the beach trail turns *mauka* and joins the 1871 Trail, the chief's house complex is in a very accessible area and is adjacent to the remnants of a modern enclosure containing salt pans or vats, a well-preserved cattle chute, and a house platform (Fig. 1). The walls of this enclosure were previously disturbed to make way for the existing beach trail. To the east of the complex are the foundations of a chapel and a conspicuous trailside *papamū*. The archaeological complex and adjacent historical features provide excellent opportunities for interpretation of both the Hawaiian period before European contact and the historic period.

Current vegetation within the Chief's house complex is very sparse and is composed primarily of alien herbs and low shrubs. One large *kiawe* tree and one coconut palm are prominent in the northwest corner of the complex. The paucity of vegetation within the walls of the house site suggests that alien woody plant removal has been done in the past, perhaps when 32 ha (80 a) were cleared of alien vegetation in 1963 (National Park Service 1994a). Vegetation at the adjacent salt pans also has been recently treated and cleared. An eight-year-old photograph of the salt pan shows a dense cover of low grass and shrubs (Greene 1993). At present, the flat site on which the concrete salt vats rest is vegetated with alien grasses and shrubs. The primary grass at this coastal site is Bermuda grass and the dominant shrubs are *ēkoa* and coffee senna (*Senna occidentalis*). The native beach shrub *naupaka kahakai* grows along the coastal road directly *makai* of the salt vats. The cattle chute or corral is clear of vegetation at its front, but has a dense stand of *ēkoa* within its walls and is surrounded by this and other alien shrub species. Other features within the modern enclosure walls are not visible because of the alien shrub cover. The adjacent chapel foundations are likewise covered with *ēkoa* and other alien shrubs; only the foundations nearest the trail are currently visible.

Current or past vegetation management at site. - At present, alien vegetation is controlled through the use of herbicide (Roundup) at the salt vats, on the *makai* side of the cattle chute, and along the trail that passes the chief's house complex (PUHO files). The current dominance of Bermuda grass in the partially cleared area may be explained by the resistance of this species to the herbicide Roundup. Current levels of vegetation management require approximately 3-4 days per year for herbicide treatment (PUHO files) and an equivalent amount of time for manual alien plant removal at this site (Victor Bio, pers. comm. 1997). Past management included removal of most alien woody species within the chief's house complex and around the

nearby historical features, as much of the coastal portion of the Park was cleared of alien vegetation more than 30 years ago (National Park Service 1976; 1994a).

Vegetation management needed to achieve desired condition. - If the Park desired to expose more of the cattle chute or other features within the modern enclosure, many more worker days per year would be required. Further clearing of these modern features is not a priority for the Park, as these features are not considered essential for interpretation (Brown 1997). Removal of some *ēkoa* from the chapel foundation would be a small addition to the vegetation management workload (perhaps 2-3 days/year) and would enhance the interpretation of the site. Removal of one very large *kiawe* tree within the wall of the chief's house complex is warranted, to prevent further damage to this important archaeological feature; this one-time project would require a team of tree removers for an unknown number of days. The best spot for viewing the chief's house complex is on a rocky rise along the trail at the chapel foundations; this open viewing area should be maintained.

Recommendations:

- Continue alien plant control within the chief's house complex, along the beach trail, and in the vicinity of salt pans and cattle chute.
- Remove one large *kiawe* tree from within enclosing wall at the chief's house.
- Clear alien shrubby vegetation from an area near the foundations of the historic chapel to permit interpretation of this site and to provide a clear spot from which to view the *Keawe* house complex and nearby historical features.

Restoration of native or Polynesian plants. - This area was likely open and only sparsely vegetated in the pre-European contact period when it was heavily used by its Hawaiian residents. While Polynesian plants may have been present, none is recommended for this area. Restoration of *loulu*, an endemic palm, along the shore to the south or west of the chief's residence would be a positive addition to the Park and is justified by the evidence of nearby lava tree molds that appear to represent *loulu* palms (Emory 1986c). Hawaiians are known to have planted these useful native palms near their dwellings (Beccarl and Rock 1921). *Loulu* palms were used in the past to provide thatching for buildings, and the small fruits of the palm were readily eaten and apparently tasted somewhat like young coconut (Neal 1965).

Recommendation:

- Restore native *loulu* palms to a coastal site south of the *Keawe* house complex.

Hōlua sites: Hōnaunau, Kēōkea, and Ki`ilae

Description of features and vegetation. - Three of the five *hōlua* known from the *Hōnaunau* area are entirely or partly within the Park. *Hōlua* are slides constructed of stone on a natural slope for a sport in which Hawaiians (largely *ali`i)* would side down a hill on a long, narrow wooden sled. This sport was a game of strength and skill, in which the winner was the contestant who sledded the farthest (Emory 1986c; Ellis 1969). While today only the stones of the *hōlua* remain, during use the sled track would have been covered with packed soil and layers of grass (Hiroa 1964). All three of the Park's *hōlua* are considered to be major archaeological features and are listed as such on the National Register of Historic Places (Greene 1993). There is some evidence that *hōlua* construction dated from a narrow period of Hawaiian history (1793-1840), and that the *hōlua* of the Park are not ancient features (Ladd 1986a).

Hōnaunau Hōlua is a relatively short feature (ca. 176 m or 580 ft) that Emory (1986c) speculated had either not been completed or was used only as a practice run. Others have questioned that this feature was really a sledding track (Robert Hommon, pers. comm. 1996). A platform at the *mauka*, eastern end of the *hōlua* may be a latter addition, perhaps a gravesite (Emory 1986c). The Park has in the past considered this accessible *hōlua*, nearest to the Pu`uhonua and Visitor Center (Fig. 1), a likely candidate for restoration and

interpretation (National Park Service 1994a). The *hōlua* was stabilized in the 1960s (Greene 1993). The vegetation surrounding the *Hōnaunau Hōlua* is almost entirely alien, consisting primarily of shrub species. The dominant shrub is *ēkoa*, but Christmas berry, *klu*, lantana, and *`opiuma* are also present. Natal redtop grass is conspicuous at the base of the *hōlua* near the 1871 Trail.

Kēōkea Hōlua, just north of the *Keanae`e Pali*, is the longest of the three *hōlua* within the Park (391 m or 1,290 ft); it stretches from a point upslope and east of the Park's boundary to the flat area *makai* and west of the 1871 Trail (Fig. 1). The upper part of the *hōlua* was "virtually intact" when examined by Emory in 1957, but the lower part is difficult to see because most of its stones were removed for use in the more recent trail (Emory 1986c). The vegetation on and around the upper part of the *hōlua* is dominated by *ēkoa,* and the same alien shrubs are present here that are at *Hōnaunau Hōlua*. The lower, less visible portion of the *hōlua* is also covered by alien shrubs, primarily *ēkoa* and *`opiuma*, but Natal redtop grass and other alien herbs are also common near the 1871 Trail.

Ki`ilae Hōlua*, in the southeast corner of the Park, was not noted by Emory in 1957 (Emory 1986c) and was not recognized as an Hawaiian sledding track until the 1960s (Ladd 1986a). This was one of Edmund Ladd's most important discoveries during his fieldwork and excavations in *Ki`ilae Village (Greene 1993). Relatively small, the *hōlua* extends for 90 m (300 ft) just north of the Park's southern boundary, and its upper reaches are outside the Park to the east. The slide is also narrow, ranging from 1.5 to 2.4 m (5-8 ft) in width. Ladd found that most of its surface stones were missing, but the *hōlua* walls were largely intact. The vegetation in this portion of the Park consists of tall closed *ēkoa* and *kiawe* with a dense ground cover of Guinea grass (Pratt and Abbott 1996a). Dense grass covers the *hōlua* and all other archaeological features *mauka* of the 1871 Trail, completely hiding them from view. The smallest and least conspicuous of the three *hōlua* in the Park, *Ki`ilae* is a lower priority for management than are the other two more accessible features (Gordon Joyce, pers. comm. 1997).

Current or past vegetation management at site. - *Hōnaunau Hōlua* may have been included in the part of the Park cleared of vegetation in the 1960s; at any rate it was likely cleared during excavation and stabilization. This feature is one of the important sites currently receiving vegetation management. Recently (1996) all alien shrubs on the *hōlua* were cut and treated with the herbicide Garlon 3A (triclopyr) in seawater, and alien herbaceous vegetation was sprayed with Roundup where necessary (Victor Bio, pers. comm. 1996). This initial clearing (after many years of little management) required approximately one month of one worker's time plus the efforts of several volunteers. Periodic spot follow-up treatments are necessary to maintain the *hōlua*.

Kēōkea Hōlua was cleared of alien plants in the past year, but current vegetation management is focused on the lower portion of the feature near the 1871 Trail (Victor Bio, pers. comm. 1997). *Ki`ilae Hōlua* has not been cleared of alien vegetation since its discovery in the 1960s, although it may have been less obscured by grass in the past when grazing cattle strayed into the Park from adjacent ranching operations prior to the construction of a stock-proof fence.

Vegetation management needed to achieve desired condition. - The recent clearing of the relatively short *Hōnaunau Hōlua* required a month of work from one trained staff member and several volunteers. Maintenance of this cleared area will require approximately 1-2 worker days per month. While it is justified to continue low-level maintenance of this accessible feature to allow for interpretation of a hōlua (National Park Service 1994a), the continued overall clearing of the much larger *Kēōkea Hōlua* will require additional funds for periodic maintenance. Removal of alien vegetation from the upper, more intact portion of the *Kēōkea Hōlua*, will require at least twice as much time as was expended on *Hōnaunau Hōlua*. *Ki`ilae Hōlua* is not currently visible or accessible to Park visitors. Vegetation management of this feature should be accomplished only in the context of a larger *Ki`ilae* Village project, and should not proceed until the *hōlua* is stabilized. If this project were programed, it would involve the herbicide treatment of cut stumps of *ēkoa* and

kiawe and the foliar spraying of Roundup on Guinea grass, probably after cutting the large clumps of grass. It is difficult to estimate effort required, but it would probably take less time than was expended on the longer *Hōnaunau Hōlua* to clear the relatively short length of *Ki`ilae hōlua*

Recommendations:

- Maintain the current cleared condition on *Hōnaunau Hōlua* by periodic treatment of reinvading alien vegetation.
- Continue removal of alien vegetation of *Kēōkea Hōlua* only if staffing is adequate to allow annual or twice yearly clearing of alien shrubs and periodic maintenance.
- Postpone clearing on *Ki`ilae Hōlua* until features are stabilized and a plan can be developed for the entire *Ki`ilae* Village site.

Restoration of native or Polynesian plants. - No plants should be intentionally introduced on or immediately adjacent to the three *hōlua,* but it would be appropriate to have the indigenous *pili* nearby, since this grass was apparently used to provide a smoother surface for the sleds during use of the hōlua (Hiroa 1964).

Recommendation:

- Plant native *pili* grass in a demonstration area near *Hōnaunau Hōlua.*

Keanae`e/Alahaka Pali, Alahaka Heiau, and Alahaka Ramp

Description of features and vegetation. - The *Keanae`e* or *Alahaka Pali* is the most prominent geological feature of the central section of the Park. This very steep cliff is covered with cascades of ropy *pāhoehoe,* a geological feature that greatly impressed early European visitors, such as William Ellis in 1823 (Emory 1986c; Ellis 1969). Within the cliff are several large caves (lava tubes) that were used as burial sites and habitations; at the base of the *pali* are a number of natural shelter sites that were modified in ancient times for human uses (Emory 1986c). The burial caves have been secured from vandalism by gates in the last 20 years. While the upper edge of the cliff does not appear to support many archaeological or cultural sites, the plain between the base of the *pali* and the ocean is rich in important archaeological features. The most prominent are an ancient platform known as *Alahaka* or *Keanae`e Heiau* and the *Alahaka* Ramp at the southern terminus of the cliff (Fig. 1).

The *heiau* is apparently an ancient structure, perhaps a *Hale o Lono* or agricultural temple (Stokes and Dye 1991), and is notable for its carefully fitted stone walls and its *pao* construction (Emory 1986c). Emory thought *Alahaka* was contemporaneous with *`Āle`ale`a Heiau* within the Great Wall; this would date *Alahaka* at about 1500 A.D. Although some of its platform stones were taken in modern times to build a nearby goat pen, the *Alahaka Heiau* has been stabilized and has great interpretive potential because of its close proximity to the 1871 Trail (Greene 1993). The *Alahaka* Ramp, which was rebuilt in its present form in 1868, has also been stabilized. This ramp, an unusual feature in Hawaiian trails, was preceded by an earlier ramp in the 1820s and by an even earlier ladder that enabled travelers to ascend the *pali* at its seaward terminus (Apple 1965). An ancient platform is visible at the base of the ramp; this may have supported a house where a guard or tollkeeper lived (Emory 1986c).

There is little vegetation on the face of the *Keanae`e* or *Alahaka Pali*, but the view of the dramatic cliff from the 1871 Trail is obscured by alien shrub cover on the plain, primarily *ēkoa* and tall *`opiuma.* The most recent vegetation map of the Park mapped this area as open *ēkoa* shrubland with other mixed exotics (Leishmann 1986). By 1993, the vegetation cover had become a dense, closed shrubland dominated by *ēkoa* and *`opiuma;* this tall shrubland also supported more than 20 other alien plant species, a few Polynesian introductions, and native species (these concentrated at the base of the pali) (Pratt and Abbott 1996a). By contrast, a 1919 photograph of *Alahaka Pali* from the trail shows a vegetation cover of low stature shrubs,

possibly *`opiuma*, with scattered *kiawe* trees (Emory 1986c). While the shrub cover was relatively dense, it did not obscure the *pali* from view. Earlier, the vegetation is said to have been even sparser (National Park Service 1976; Greenwell 1986). Another old photograph of the base of the pali in 1919 shows scattered *`opiuma* shrubs and papaya (*Carica papaya*) (Emory 1986c). While *Alahaka Heiau* remains visible from the 1871 Trail, it is surrounded by alien shrubby vegetation. The adjacent goat pen is filled with tall *ēkoa* shrubs and has a cover of low-growing mixed alien species and indigenous *`uhaloa* between the structure and the trail. The *Alahaka* Ramp and the adjacent house platform are largely free of vegetation. The area *makai* of the 1871 Trail near *Alahaka* is relatively open with scattered *ēkoa, `opiuma, noni,* and other low-stature alien shrubs, grasses, and vines.

Current or past vegetation management at site. - The *Alahaka Heiau* itself has been cleared of vegetation in the past (most thoroughly during stabilization by Somers in 1986), and there is current management of alien plants in the area separating the *heiau* and the adjacent goat pen from the 1871 Trail. While *ēkoa* and *`opiuma* are the dominant shrubs *mauka* of the *Alahaka Heiau* and within the nearby goat pen, these shrubs have been largely cleared between the features and the trail. The vegetation in this managed area is now composed of scattered low coffee senna, hairy spurge, beggarweed (*Desmodium* spp.), *`uhaloa*, and the viny balsam pear or bitter melon (*Momordica charantia*). *Makai* of the trail near *Alahaka Heiau*, the relatively open vegetation also appears to have been cleared or thinned in the past. The *Alahaka* Ramp is bare of vegetation and has likely benefitted from past clearing. The adjacent platform has been recently cleared, although young *`opiuma* trees and the shrub species *ēkoa*, coffee senna, and coral plant (*Rivina humilis*) have begun to re-invade. The platform also has considerable cover of the alien vines balsam pear and scarlet-fruited passion flower. Stacked remains of trees previously cut are conspicuous at the base of the ramp. Current vegetation management of spraying mixed alien plant species with Roundup herbicide requires at least 6-7 worker days per year at *Alahaka Heiau* and the adjacent goat pen, and additional time at sites near *Alahaka makai* of the 1871 Trail (PUHO files). Manual removal of alien plants at and near *Alahaka* requires approximately the same effort as herbicide work (Victor Bio, pers. comm. 1997).

Vegetation management needed to achieve desired condition. - Without this current level of vegetation management, the ancient *heiau* and the modern goat pen would be completely overgrown and invisible to visitors on the 1871 Trail. The herbicide treatment of the area between the *heiau* and the trail should be continued, and extended slightly to the north to provide a clear view of *Alahaka Heiau* from a slight rise on the trail. For enhancement of interpretive opportunities at *Alahaka Heiau*, it would be desirable to clear alien shrubs, primarily *ēkoa* and *`opiuma,* from the entire perimeter of the *heiau,* thus permitting a view of the unusual smooth rock facing noted by Emory (1986c). Such clearing would require at least 2 days/year and additional time for periodic maintenance. Clearing the *ēkoa* from within the goat pen is probably not warranted, as interpretation of this modern structure is possible with the current level of management, which keeps vegetation clear of the walls facing the 1871 Trail. Another desirable addition to vegetation management at the *Alahaka* site is the partial clearing of tall *`opiuma* trees *mauka* or east of the *heiau.* These tall trees interfere with the view of the imposing *Keanae`e* Cliffs. The current landscape is much more densely vegetated than it was 80 years ago, and vegetation is obviously much taller and thicker than when Ellis viewed the area in 1823 (Ellis 1969). Cutting *`opiuma* and tall *ēkoa* behind the *heiau* to restore the cliff view from the trail would be a large project initially, but annual follow-up treatment of the shrubs would require a lesser commitment of time. If only the area near *Alahaka* were cleared, a view of the cliffs could be re-established with approximately 5-10 days of clearing work; maintenance of this view would require at least 1 day/year. It is probably not desirable to clear a path to the base of *Keanae`e Pali*, even though significant features are found there. A clear path would encourage more visitation of the area, and this might lead to increased vandalism at the burial caves and other sensitive sites.

The narrow band *makai* of the 1871 Trail at *Alahaka Heiau* would certainly benefit from increased attention; the addition of several worker days/year would be required to clear the scattered shrubs and trees in this area, mostly *`opiuma, ēkoa*, and *noni.* The scattered *`uhaloa* shrubs and low herbaceous alien

vegetation should be left, as such vegetation does not interfere with the view of the coastline and ocean. It is probably not necessary to have completely bare *pāhoehoe* here to restore a cultural landscape; the cut-stump treatment of the target woody plants is less time-consuming to accomplish, and uses far less herbicide than foliar spraying of tall shrubs. Shrub clearing should be continued at the ancient platform near the base of *Alahaka* Ramp and perhaps a few extra days/year allotted to maintenance of the cleared vegetation. The alien vines currently invading the area should be controlled on a more frequent rotation. It is desirable to remove the remnants of cut trees stacked at the base of the *Alahaka* Ramp, which somewhat detract from appreciation of the archaeological features.

Recommendations:

- Continue to keep the surface of *Alahaka Heiau* clear of alien plants and continue the periodic treatment of weeds in the area between the *heiau* and the 1871 Trail.
- Clear a corridor around the perimeter of *Alahaka Heiau* to enhance visitor appreciation and interpretation of the *heiau*.
- Cut and remove tall *`opiuma* and *ēkoa trees* behind (east of) the *heiau* to restore the cliff view from the trail.
- Clear scattered shrubs and trees makai of the 1871 Trail in the *Alahaka* area; species to be cut are *`opiuma, ēkoa*, and *noni.*
- Continue shrub clearing at the ancient platform near the base of *Alahaka* Ramp; remove the stacked remnants of cut trees at the base of the ramp.

Restoration of native or Polynesian plants. - There is no pressing need to restore native or Polynesian vegetation to the *Alahaka* area. The indigenous shrub *`uhaloa* is common in this area and requires no special management to maintain itself. *Noni*, a Polynesian introduction, is scattered throughout the site, and in fact, may need to be removed from several small areas to enhance viewing of the coastline and archaeological features. Several native plant species are restricted in the Park to the base of the *Keanae`e Pali*; examples are *`ala`alawainui*, spurflower (*Plectranthus parviflorus*), and a small fern *Doryopteris decora*. No special management of these species is required, other than to avoid damaging them in the course of alien plant control.

Recommendation:

- No plants are recommended for restoration at this site.

Ki`ilae Village

Description of features and vegetation. - *Ki`ilae* Village is an extensive site in the southern part of the Park; a portion of the village is outside the Park boundary to the south on *Kaimalino* Ranch. The part of the village excluded from the Park contains an extensive lava tube, a spring and well, and the house site of the Chiefess *Kekela*, mother of Queen Emma (Emory 1986c). The larger part of the village within the Park extends from *`Ahinahina* Point to the southern boundary of the Park (and *Kēōkea ahupua`a*) along *Ki`ilae* Bay (Fig. 1) and contains a number of house sites, pens, walled enclosures, platforms, tombs, graves, and at least one *heiau* (Emory 1986c). *Ki`ilae* Village was occupied until about 1926 (Greene 1993), and is thought to have been first settled in the early 1800s, making it an historical but not ancient village (Ladd 1986a). A cultural history study was made of *Ki`ilae*, so much is known about the life of the village (Jackson 1966). Apparently, the villagers survived by fishing at the end of the period of occupancy, but farming and animal grazing had also helped support the village in the past (Greene 1993). The village was composed of a mix of traditional thatched houses and more modern wooden ones, and gravesites vary from traditional stone platforms to concrete tombs. The significance of *Ki`ilae* and its recognition on the National Register of Historic Sites are derived from the mixture of traditional and modern lifestyles exhibited by the village remains and the persistence of the inhabitants into the 20th century.

The village was surveyed, mapped, and excavated by Ladd in the 1960s, and apparently there was a plan to restore the village that was never carried out. The Park's long-term interpretive plan recognizes this site as significant for the interpretation of Hawaiian daily life (Brown 1997). Although Park documents acknowledge the importance of *Ki`ilae*, it is uncertain how many people actually visit the site. One guide to Hawai`i Island walking trails discourages hikers from traveling beyond the southern end of *Alahaka* Bay, rating the trail here as "very overgrown" (Morey 1995). Morey's assessment of the trail is perhaps based on old information; researchers from Hawaii Volcanoes National Park periodically visiting P`uhonua o Hōnaunau NHP have found the trail clear since 1993. It would be instructive to have a count of daily visitors to the *Ki`ilae* Village area before additional vegetation management is proposed for this site.

The current vegetation of *Ki`ilae* Village is almost entirely alien, and a dense cover of *ēkoa*, *kiawe*, and Guinea grass obscure most of the features above the 1871 Trail. Only walls of house site enclosures directly adjacent (*mauka*) to the trail remain visible here. Below the trail, periodic clearing of alien vegetation has resulted in a more open alien vegetative cover of scattered *kiawe* trees, *ēkoa* and *`opiuma* shrubs, and more than 15 additional alien species of herbs, vines, and low shrubs. Traveling from north to south along the 1871 Trail, the first obvious *Ki`ilae* Village feature encountered is the *Ahu* Homestead, a historic complex consisting of a house platform, "cellar", concrete cistern, concrete tomb, and enclosing walls. This complex is located *makai* of the trail on *`Ahinahina* Point, just south of the *Alahaka* Ramp. A wooden house was built here in the 1890s, but it was relocated to *Hōnaunau* in the 1930s (Greene 1993). Scattered trees grow here, including *kiawe*, several tamarinds and one large plumeria adjacent to the tomb. Other than these ornamentals and potential shade trees, the vegetation is a scrubby alien mixture of low shrubs and herbs with a conspicuous patch of hairy abutilon (*Abutilon grandifolium*). The narrow stretch of land *makai* of the trail to the south has no obvious features until the southern shore of *Waha`ula* Cove inland of *Halakahi* Point, where there are several old house sites enclosed by walls. The vegetation here is scattered *kiawe* trees with a mix of low-growing alien shrubs and herbs, including hairy abutilon. Nearby are a relict planting of aloe (*Aloe vera*) and several young coconut palms, possibly of the Samoan type that fruit while relatively short. To the south, just inside the Park boundary is a feature identified as *Ka`akapua Heiau* (Emory 1986c); an attached fishing shrine is over the line on private land. The *heiau* has obviously been cleared of alien vegetation in the recent past, but there are a few remaining patches of annual herbs (*Bidens cyanapiifolia*, *Chamaesyce hirta*, *Amaranthus* sp.), patches of Guinea grass, and persistent coffee senna shrubs. Several large *kiawe* trees are scattered nearby, *makai* of the *heiau*.

Current or past vegetation management at site. - Other than trail clearing, *Ki`ilae* village ruins *mauka* of the 1871 Trail have not received any recent vegetation management; presumably some clearing was done during the mapping and excavation fieldwork of Edmund Ladd in the 1960s. The area *makai* of the trail is periodically treated with herbicide (Roundup), at least from the *Ahu* Homestead to the Park's southern boundary. In addition, Guinea grass is treated and removed a short distance *mauka* of the trail to the enclosure walls. The Park staff is unable to keep this *makai* part of the village completely clear of alien ground cover. Approximately 8 days/year are expended in the attempt to maintain past vegetation clearing using herbicides (PUHO files), and an equivalent amount of time is spent in manual control of alien plants here (Victor Bio, pers. comm 1997). The boundary fenceline that passes through the village (and crosses the *hōlua*) is sprayed and cleared of alien vegetation three times a year to maintain a fuel break and monitor for incursions of grazing animals and feral pigs. The fenceline and an area where water flows downslope during periods of high rainfall must also be periodically checked for fountain grass that occasionally invades the Park from the adjacent ranchland (Victor Bio, pers. comm. 1997). The 1980 1:100,000 map of Hawai`i County shows *Ki`ilae* Watercourse as an intermittent stream fed by a swampy area upslope.

Vegetation management needed to achieve desired condition. - The complete clearing of alien vegetation from *Ki`ilae* Village is obviously beyond the ability of the Park to accomplish or maintain with the current staffing level, because of the size of the vegetation management workload elsewhere in the Park. Also, the features above the trail have not been restored (as originally planned) or even stabilized. Extensive

vegetation management above the 1871 Trail is not warranted at this time. However, it would be desirable to maintain the relatively more open conditions that the current level of management has been able to accomplish *makai* of the trail. The area *makai* of the trail is the only part of *Ki`ilae* that is currently considered a priority for management by the Park staff (Gordon Joyce, pers. comm. 1997).

Recommendation:

- Maintain the open condition of *Ki`ilae* Village site *makai* of 1871 Trail.

At the historical *Ahu* Homestead, it is desirable to leave the large *kiawe* trees near the trail to provide shade for visitors walking along the 1871 Trail. Beneath the largest *kiawe makai* of the trail is an obvious stopping place for viewing the remains of the *Ahu* Homestead. Periodic treatment of the alien vegetation in this area (mostly low shrubs and herbs) should continue. As some of the limbs of the scattered *kiawe* are leaning low and obscuring some of the features of this site, it is desirable to cut back some of the drooping limbs. On the shore directly *makai* of the *Ahu* Homestead features, several small *kiawe* and *`opiuma* are blocking views of the coastline and the northern part of the Park. Removal of a few small trees here would greatly enhance this site for visitors. The several tamarind trees and the lone plumeria should be left in place, as they are part of the historic landscape.

Recommendations:

- Continue to treat low-growing alien vegetation at the *Ahu* Homestead.
- Limb *kiawe* trees at the trailside viewing spot.
- Remove several small *kiawe* and *`opiuma* blocking coastline views *makai* of the *Ahu* Homestead.
- Retain large *kiawe* shade trees and historic plumeria and tamarinds.

South of the *Ahu* Homestead, the narrow strip of land *makai* of the trail has been cleared in the past. It is desirable to remove the scattered young alien trees and shrubs (particularly coffee senna) that interfere with views of the sea and coastline, but it is probably not necessary to spray all vegetation in this area, as the low-growing native *`uhaloa* and alien Madagascar periwinkle and vines are unlikely to obscure views and are not damaging any obvious features here. At one point south of the *Ahu* Homestead, a patch of very tall Guinea grass is encroaching on the trail, and appears to have blocked the trail in the recent past. This one patch of grass should be cut and treated to clear the trail and provide continued access to *Ki`ilae* Village.

Recommendations:

- Remove scattered alien trees and shrubs makai of trail blocking coastal views.
- Treat one patch of Guinea grass encroaching on the 1871 Trail.

The *heiau* and house sites makai of the trail at the southern extremity of the Park have also received intensive management of vegetation in the past, and current vegetation consists of scattered *kiawe* trees and mixed alien herbs and low shrubs. The scattered *kiawe* trees remaining in this area should be left in place to provide shade until the Park develops a program to replace them with native or Polynesian trees. One *kiawe* tree growing directly adjacent to a wall north of the *heiau* should be removed to prevent damage to the archaeological feature. Other *kiawe* trees near the *heiau* should be limbed where they are touching and obscuring the features; this limbing will also improve the view to the sea from this site. The patch of aloe associated with the old house sites here should be left, as it represents an element of the historic landscape. The few remaining *`ilima* in this area should be allowed to persist. The only other native plant noted in this area is the beach sedge *Fimbristylis cymosa* (Pratt and Abbott 1996a); current vegetation management is unlikely to disturb this hardy coastal plant.

Recommendations:

- Continue to treat alien vegetation at *Ka`akapua Heiau* and house sites *makai* of trail.
- Remove one *kiawe* tree growing on a feature wall.
- Limb *kiawe* trees touching and leaning over the *heiau*.

Restoration of native or Polynesian plants. - While a number of Polynesian plants (and later introductions as well) were probably part of the landscape of *Ki`ilae* village during its period of inhabitation, it is difficult to select which are most appropriate to plant at *Ki`ilae*. Information gathered during preparation of a cultural history of *Ki`ilae* indicated that cultivation of food plants such as *kalo* or *taro,* sweet potatoes, yams, sugarcane, and squash (*Cucurbita* sp.) took place in upland gardens outside the Park (Jackson 1966, cited in Greene 1993). Documentation does not exist to warrant planting of crop plants within the *Ki`ilae* Village complex, and the area is probably too dry to support such plants. However, small-scale re-introduction of typical Polynesian plants such as *kī* may be justified near one or more housesites makai of the trail, if such outplanting does not interfere with the protection of the archaeological and historical features of the site. If Park goals eventually require the removal of the scattered *kiawe* trees currently providing shade near the features receiving vegetation management, Polynesian and native tree species should be used to replace these alien shade trees. Possibilities are *noni, kukui*, and *kou*, all currently found within the Park.

Recommendations:

- Evaluate Polynesian plants for outplanting in the currently cleared section of *Ki`ilae* Village.
- Plant *kī* shrubs at suitable sites along the 1871 Trail within *Ki`ilae* Village, where the plant is appropriate to the historical scene.

1871 Trail and Trailside Vegetation

Description of features and vegetation. - The 1871 Trail is the longest and most prominent walking trail in the Park, stretching from the Visitor Center area to the Park's southern boundary (Fig. 1). This trail was constructed in 1871 to accommodate horse traffic and apparently followed the route of an earlier trail. Apple (1965) called this type of straight, curbed trail, constructed after 1840, a "type C" trail. The portion of the trail that has been reconstructed within the Park is about 3 m (10 ft) wide and has a raised bed covered with coral, sand, or pebbles (Greene 1993). The trail is most conspicuous where it has been reconstructed between the unpaved access road to Park administration buildings and the *Alahaka* Ramp. Beyond the ramp to the south, the trail has not been resurfaced, and curbstones have not been replaced, but the route of the straight trail is distinct to the boundary and beyond the Park. This trail is the primary route from the Visitor Center to most of the important archeological features in the Park, including two of the Park's *hōlua*, *`Ōma`o Heiau, Alahaka Heiau, Keanae`e Pali*, the *Alahaka* Ramp, and *Ki`ilae* Village. The coastal trail turns *mauka* and joins the 1871 Trail near the *Keawe* House site. Although it is one of the features listed on the National Register of Historic Sites (Greene 1993), the 1871 Trail is not discussed as a significant Park resource in the recent Long-term Interpretive Plan (Brown 1997).

Vegetation along the 1871 Trail is varied. Near the Visitor Center the trail passes through a coconut grove, but most of the route to the *Alahaka* Ramp passes through a low shrubland of *ēkoa,* other alien shrubs, and Natal redtop grass. There is a grove of relatively dense *noni* trees adjacent to the trail south of the Visitor Center and east of the Great Wall. The southern portion of the trail beyond the ramp passes a few *kiawe* trees, but the dominant vegetation *mauka* of the trail is tall closed *ēkoa* with dense Guinea grass (Leishmann 1986, Pratt and Abbott 1996a). Tall, spreading monkeypod trees grow along the trail between the visitor center and the *Alahaka* Ramp; these provide welcome shade to visitors hiking the trail. The surface of the reconstructed trail is nearly bare of vegetation, but the unrestored section has a number of alien grasses and herbs, as well as the native *`uhaloa*, scattered along its length.

Current or past vegetation management at site. - The reconstructed portion of the trail is currently kept clear of vegetation by the periodic application of herbicide (Roundup); this work requires approximately 3-4 days per year for herbicide treatment (PUHO files) and a few additional days for manual removal of weeds. Less attention is given to the trail south of *Alahaka* Ramp, but trail clearing is done in conjunction with vegetation management of the *Ki`ilae* Village site. The 1871 Trail was not yet completely cleared when the first comprehensive Natural and Cultural Resources Management Plan was written more than 20 years ago (National Park Service 1976), but the trail has subsequently become an important element in the logistics of visitor flow through the Park.

Vegetation management needed to achieve desired condition. - The current level of support for vegetation management only allows the Park to maintain the 1871 Trail from the Visitor Center to the *Alahaka* Ramp. This amount of maintenance is essential to permit access to many of the Park's significant archaeological and historical resources away from the *Pu`uhonua*. If Park managers wish to encourage visitor use of the area south of the *Alahaka* Ramp, a greater commitment of vegetation management will be required to better maintain the 1871 Trail in this area. Several additional days per year will be necessary to treat vegetation encroaching on the trail in the *Ki`ilae* Village; such a commitment will be an important precursor to any additional clearing of features in the village. One large patch of Guinea grass that is currently blocking the trail between the *Ahu* Homestead and the *heiau* at the southern Park boundary should be treated as soon as possible.

Recommendations:

- Continue to maintain the 1871 Trail from the Visitor Center to *Alahaka* Ramp by periodic treatment of alien plants on the trail surface.
- Clear one large patch of Guinea grass encroaching on the 1871 Trail in *Ki`ilae* Village.
- Carry out the maintenance required to keep the 1871 Trail passable from *Alahaka* Ramp to the Park's southern boundary. More time-consuming clearing should await trail reconstruction and a plan to stabilize and interpret *Ki`ilae* Village.

Restoration of native or Polynesian plants. - Currently alien *kiawe* and monkeypod trees are providing shade at intervals along the length of the 1871 Trail. As shade is highly desirable for hikers along the trail, these large trees should be allowed to remain in areas receiving vegetation management, unless their roots are damaging archaeological and historic features. If alien shade trees must be removed from the verge of the 1871 Trail, they should be replaced with Polynesian or native tree species. Suggested species to use as replacement shade trees are *kou*, *kamani*, *noni*, and *hala*; all of these species are currently growing elsewhere in the Park. The first three are Polynesian introductions, and *hala* is an indigenous species. As with other projects requiring propagation of native or Polynesian species for outplanting in the Park, the services and nursery of the Amy Greenwell Ethnobotanical Garden should be used, if possible.

Recommendations:

- Retain alien monkeypod trees for shade along the 1871 Trail.
- If monkeypod or other large alien shade trees must be cut on the verge of the trail, replace them with plantings of Polynesian tree species appropriate to the Park (for example, *kou, kamani, hala,* or *noni*).

Upland Garden and Native Species Outplantings

Description of features and vegetation. - The upland garden is located in a 1.5 ha (3.7 a) parcel of land not contiguous with the rest of the Park. Also known as "*Kihapai uka*," the garden is approximately 5 km (3 miles) upslope of the Park on Highway 160 that connects the Park to the *Māmalahoa* Highway. The parcel supports two structures: a large dormitory and environmental education facility and a smaller storage building. There are no known archaeological features within the parcel. The grounds between the dormitory and the

road, as well as a portion of the grounds behind the buildings, have been cleared of alien growth and planted with representative native and Polynesian species. Approximately the upper third of the parcel remains uncleared and is covered by a thick growth of alien shrubs and grasses among which a number of large *kukui* are scattered.

The upland garden was originally conceived as a site for the propagation of native and Polynesian material for outplanting in the main Park (National Park Service 1976). As the site does not contain a formal propagation facility, this function may be more efficiently carried out by Amy Greenwell Ethnobotanical Garden in Captain Cook, with which the Park Service has a Memorandum of Understanding. If the Park wishes to do extensive plant propagation in-house, facilities here will need upgrading. The upland garden site has also been used to grow demonstration materials and examples of useful native and Polynesian plants for display in the Park, and these uses will likely continue. Another recently articulated purpose of the garden is to provide a self-guided interpretive trail with labeled native and Polynesian plants for visitor education. Plants with ethnobotanical uses are emphasized in interpretation. The upland garden is scarcely mentioned in the recent long-range interpretive plan; references are made to the garden as a site where visitors can learn about Hawaiian plants and as the location of an environmental education center (Brown 1997).

Approximately 50 native and 15 Polynesian plant species (as well as nine alien plants used medicinally) have been planted in the developed portion of the upland garden; among these are nine listed endangered plant species (*Abutilon menziesii, Caesalpinia kavaiensis, Colubrina oppositifolia, Hibiscadelphus giffardianus, Kokia drynarioides, Pleomele hawaiiensis, Pritchardia affinis, P. shautaueri, Sesbania tomentosa*). Not all of these endangered species are extant in the garden; several have died since they were originally planted. Most of the planted endangered species were identified on the most current list of outplantings in the upland garden (National Park Service 1993b). The source of these endangered species was the Division of Forestry and Wildlife in Hilo; they were derived from previously propagated material. The Park does not currently have a State permit to hold endangered plant species. A Federal Endangered Species permit is not required because these plants were from propagated material, and were not from the wild (Marie Bruegmann, pers. comm. 1997).

Current or past vegetation management at site. - Current vegetation management involves several priorities at the upland garden; the first priority is control of alien vegetation in the already cleared area through weedwhacking, burning, hand pulling, and foliar application of the herbicide Roundup. When large woody alien plants must be removed, they are cut with a chain saw and chipped to use a mulch elsewhere in the garden (Victor Bio, pers. comm. 1997). Other jobs at the garden include plant fertilization, monitoring, insect control, work on the interpretive trail, and expansion of the garden upslope into the uncleared area now covered with alien shrubs and grasses. Currently 6 days/month are spent on vegetation management at the upland garden site.

Vegetation management needed to achieve desired condition. - Continued alien plant control is needed in the developed part of the garden to maintain the plantings and the interpretive trail. Without the current level of vegetation management, the cleared and planted portion of the garden will revert to a tangled growth of alien plants. Expansion of the garden to the uncleared portion of the parcel is slowly proceeding. A site management plan should be developed for the expansion that includes a list of species to be planted and documents introductions into the garden. Park staff must continue to keep records of plantings and notations of the loss of planted species. The current checklist of plantings should be updated with current scientific nomenclature, and those plant species no longer present should be deleted. A database should be developed to manage the data on outplanting, seed source, and plant survival for the upland garden. Those few alien species outplanted in the garden for which there is no cultural landscape justification or early historical use in ethnobotany should be removed; examples are air plant (*Kalanchoë pinnata*) and lemon grass (*Cymbopogon citratus*).

Recommendations:

- Continue to control alien plants in the developed part of the garden and along the interpretive trail by manual and chemical methods.
- Update the checklist of plants found in the upland garden, revising the nomenclature to reflect that currently in use (Wagner *et al.* 1990).
- Continue to keep records of outplantings, including the loss of planted species. The seed source of current outplantings and any future additions should be documented to prevent the introduction of species inappropriate to the area. Develop a database to manage outplanting data for all the species in the upland garden.
- Prepare annual reports to document new additions to the garden and losses of existing plants.
- Expand the cleared area of the garden only after a garden outplanting plan is developed.
- Remove several inappropriate plantings of alien plant species to avoid misinterpretation of traditional uses of plants in Hawaiian culture.
- Obtain a State Endangered Species permit for those endangered plants already present in the upland garden. If interpretation of ethnobotanical uses of endangered plants is desired, include this use on the permit application.

Restoration of native or Polynesian plants. - Among the 15 Polynesian plant species currently outplanted at the upland garden are most of the crop plants that would have been part of the lives of early Hawaiians inhabiting the Park. The botanist Archibald Menzies noted plants such as *kalo*, sweet potatoes, *ulu* or breadfruit (*Artocarpus altilis*), *wauke*, and *kī* growing in the gardens above *Kealakekua* Bay in 1793 (Menzies 1920). All these food and fiber plants are appropriate to the Park's upland garden. The theme for native plants chosen for the garden seems to be lowland dry and mesic forest/shrubland, although a few species more typical of wet forests have also been outplanted. Most common lowland species and several very rare dry forest trees are already represented by specimens in the upland garden. If other species are desired as additions to the garden, they should be part of an outplanting or site management plan and justified by their fulfillment of an interpretive need. Notably lacking from the upland garden are several uncommon species persisting with few individuals in the main part of the Park and a few species that appear to have been lost in the last decade. These would be appropriate additions to the upland garden, if interpretation of original vegetation and cultural landscapes is desired. Examples of uncommon native plants persisting in the Park and deserving of augmentation within the main part of the Park and outplanting in the upland garden are *pua pilo*, Hawaiian moon flower, *`ilie`e* , and *pua kala* or Hawaiian prickly poppy.

Recommendations:

- Procure seeds or cuttings of several rare native plants present in the main Park and outplant individuals in the upland garden (perhaps Amy Greenwell Ethnobotanical Garden could be used to propagate plants). This will ensure a local source of propagation material if the few plants extant in the main Park are lost.
- Develop a site management plan (outplanting and interpretive plans) for additional plants to add to garden.

Alien Plant Management at Other Sites

Alien plants that require management at specific sites not included in the list of priority sites are discussed below. Several localized alien plants that occur in low numbers at few sites should be eradicated from the Park before they become more widespread and unmanageable. For a few alien plant species that have been recently treated and eliminated from the Park, the only management recommended is monitoring to prevent re-establishment in the Park. Monitoring may be either formal or informal. When the last site of a weed infestation in the Park is well known, this site should be permanently marked and it should be periodically revisited (at least once a year and perhaps quarterly) to search for recovery of treated individuals or germination of new weed seedlings. Data on number of new seedlings or the status of previously treated

pest plants should be recorded and will provide information on whether current control strategies are working. Such monitoring will contribute to the Park's ability to manage alien plant species in the future (Tunison 1992; Tunison and Zimmer 1992). A more informal monitoring program is the periodic searching of likely points of entry into the Park, such as roadsides, trails, parking lot, dry stream beds, and fencelines, to look for invasions of new weeds or re-invasion of weeds already eliminated from the Park. When found, the species of weed and number of plants treated or killed should be recorded for the Park's Resources Management files.

Fountain Grass (*Pennisetum setaceum*)

Fountain grass, a native of northern Africa, is one of the worst invasive alien plant species in the Hawaiian Islands (Smith 1985). This large bunchgrass was introduced as an ornamental plant to the island of Hawai`i in the early 1900s, and it is now widely distributed in dry regions on Hawai`i and has also invaded Kaua`i, O`ahu, and Lana`i (Wagner *et al.* 1990). An incipient invasion on Maui may be under control.

This bunchgrass was formerly found in low numbers within Pu`uhonua o Hōnaunau NHP and was recommended for control within the Park (Smith *et al.*1986). No fountain grass was seen in the Park during the most recent botanical survey (Pratt and Abbott 1996a), and the species appears to have been eradicated from Pu`uhonua o Hōnaunau. Periodic monitoring should be carried out along roadsides and trails, as well as along the edges of the parking lot, to ensure that fountain grass does not reinvade the Park. Any clumps of fountain grass found during monitoring should be uprooted and destroyed, after removing any inflorescences for later burning. While several effective herbicidal treatments are known for fountain grass (Amerling 1997; Castillo 1997), manual control is highly effective when the infestation is small (Tunison 1992).

Pickleweed (*Batis maritima*)

Pickleweed or saltwort is a sprawling shrub with succulent, linear leaves and small, unisexual flowers borne on spikes. The species is native to tropical and subtropical America, and was first noted in the Hawaiian Islands near *Honolulu*, O`ahu in 1859 (Wagner *et al.* 1990). In less than 100 years, pickleweed had spread to all salt marshes on O`ahu and had invaded all the other main Hawaiian Islands, where it was abundant on coastal mud flats, behind beaches, and near the mouths of streams (Fosberg 1948). Because of its ability to form dense, pure stands (Whistler 1992), this species is a serious pest of coastal regions in the Hawaiian Islands.

During the most recent botanical survey of Pu`uhonua o Hōnaunau NHP, only one patch of pickleweed was recorded on the side of one of the brackish pools near the Great Wall (Pratt and Abbott 1996a). This was apparently a recent invader in the Park, as it was not noted on the previous survey carried out in the mid-1980s (Smith *et al.* 1986). The one patch of pickleweed was destroyed by Park staff during maintenance of the pools and surrounding area, and the species has not returned as of 1998. Monitoring of the margins of the several pools inside and adjacent to the *Pu`uhonua* should be sufficient to prevent the reinvasion of this undesirable species. Should pickleweed return to the Park, effective herbicidal and mechanical treatments are known for the species. Amerling (1997) has removed pickleweed from Pu`ukoholā Heiau NHS by applying a dilute solution of Rodeo, and workers at Kaloko-Honokōhau NHP have found scorching with hand-held torches to be an effective method of killing the plant (Laura Schuster, pers. comm. 1998).

Chinese Banyan (*Ficus microcarpa*)

Chinese banyan is a medium to large, evergreen tree native to southern Asia, Australia, the Ryukyu Islands, and New Caledonia. Introduced to Hawai`i as an ornamental, it is one of very few banyans to have become naturalized, because the specialized pollinating wasp was also introduced to Hawai`i (Wagner *et al.* 1990). Because of its epiphytic habit and aerial roots, Chinese banyan is potentially harmful to archaeological

sites. During the 1992-94 botanical survey of Pu`uhonua o Hōnaunau NHP, only one Chinese banyan tree was found within the Park; this was growing near one of the brackish pools between the Visitor Center and the Great Wall (Pratt and Abbott 1996a). This tree was removed by Park staff, and it was no longer present on a recent site visit to the Park (Pratt 1998a). No further action is required, except to prevent Chinese banyan from re-establishing in the Park from bird-borne seeds. Periodic visual monitoring of the developed area of the Park near the *Pu`uhonua* and Visitor Center should be sufficient to sight any invading banyan trees, which can then be destroyed. The species is apparently sensitive to both glyphosate (Roundup) and triclopyr (Redeem/Remedy) (Motooka 1995).

Autograph Tree (*Clusia rosea*)

Native to Florida and the West Indies, the autograph tree is an ornamental widely planted in cities of the dry lowlands in Hawai`i. The species is now naturalized on three islands (Kaua`i, O`ahu, and Hawai`i) (Wagner *et al.* 1990) and continues to be outplanted as a landscaping tree because its shiny green foliage and large, fleshy, star-shaped open fruits are considered attractive. It will likely continue to spread, because its red-covered seeds are eaten by birds that act as effective dispersal agents. Only one autograph tree was noted at Pu`uhonua o Hōnaunau NHP in the 1992-94 survey near the canoe shed in the developed part of the Park (Pratt and Abbott 1996a); this plant established in the Park between botanical surveys, as it was not reported by Smith *et al.* (1986). A Park staff member removed this one individual after it was reported, and the species appears to have been eliminated from the Park (Pratt 1998a). Autograph tree should be one of the potentially invasive alien plants regularly searched for in a weed monitoring program within the Park.

Prickly Pear Cactus (*Opuntia ficus-indica*)

Prickly pear cactus was an early intentional introduction to Hawai`i; it was planted on O`ahu by Francisco de Paula Marin in the early 1800s (Nagata 1985). Native to Mexico, the tree-like cactus was cultivated for its fruits and edible pads, and it was also planted as a prickly hedge (*pānini*). Prickly pear cactus escaped cultivation and is now naturalized on five of the Hawaiian Islands, where it is considered a range pest.

During the most recent botanical survey of Pu`uhonua o Hōnaunau NHP, only one prickly pear cactus plant was found on the steep *pali* near the *Alahaka* Ramp (Pratt and Abbott 1996a), and it is unlikely that there are many additional plants elsewhere in the Park. Formerly, prickly pear cactus was a more common component of the vegetation in the area (Greenwell 1986). It probably invaded the Park from nearby cattle pastures. Removal of prickly pear cactus should not be a high priority, but this species can be easily eradicated from the Park by destroying the one known individual and any other plants when they are encountered. The plant may be killed by cutting and removing the slash or by burning it in place (Lorenzi and Jeffery 1987). Herbicides were found to be ineffective on this cactus in Hawaii Volcanoes National Park (Tunsion and Zimmer 1992).

Night-Blooming Cereus (*Hylocereus undatus*)

This cactus is a sprawling, succulent vine used as an ornamental in dry areas, particularly along rock walls. Native to Central America, the plant is widely cultivated in tropical lands. This was an early introduction to Hawai`i, arriving on O`ahu as cuttings brought by the Brig Ivanhoe in 1830 (Degener 1946). Night-blooming cereus has a beautiful, large, cream-colored flower that is a common motif in modern Hawaiian decorative art. Because of its use as an ornamental and its popularity, this cactus is not often thought of as a pest. However, its succulent nature, viny habit, and persistence make night-blooming cereus a potential pest at Pu`uhonua o Hōnaunau NHP. Elsewhere in the world, night-blooming cereus is considered a "passive invader" for its ability to persist at disused habitation sites or refuse dumps (MacDonald 1983).

Night-blooming cereus was seen on a rock wall just outside the Park boundary with Bishop Estate in both recent botanical surveys (Smith *et al.* 1986; Pratt and Abbott 1996a). The cactus remains at this site adjacent to the Park, and another patch of night-blooming cereus was observed in 1998 on a pile of slash near the administration and maintenance buildings. This newly-sighted plant should be removed from the Park, and slash piles should not be used to dispose of succulent plant material removed from elsewhere within the Park. As for ornamentals planted outside its boundary, the Park can only monitor the grounds nearest the night-blooming cereus to ensure that it does not move into the Park.

Sourbush (*Pluchea symphytifolia*)

Native to tropical America, sourbush was first collected in the Hawaiian Islands on O`ahu in 1931 (Wagner *et al.*1990). Fosberg predicted that the species would do well in Hawai`i, and within 20 years, the shrub was abundant in dry lowland sites on O`ahu (Fosberg 1948). It is unknown when sourbush spread to other Hawaiian Islands, but today it is found on all the main Islands, as well as Kure, Midway, and French Frigate Shoals (Wagner *et al.* 1990). Very little sourbush was found at Pu`uhonua o Hōnaunau NHP during the last botanical survey; the shrub appeared in only one of the systematically-placed vegetation plots used to survey the Park, and one additional plant was noted along the coast near the southern Park boundary (Pratt and Abbott 1996a). Subsequent visits to the Park have indicated that sourbush is also found beneath tall shrubs just east of the temporary administration buildings. While this species is not a more serious threat to archaeological resources than are the more common alien shrubs in the Park, sourbush should be kept out of the Park's anchialine pools, and the shrub should not be allowed to expand its current range or invade newly cleared areas *makai* of the 1871 Trail. Smith *et al.* (1986) recommended monitoring and control of this species in the Park. Sourbush has been shown to be responsive to several herbicide treatments; Motooka (1995) achieved complete control of the shrub with both glyphosate (1.5 lb/acre) and triclopyr (1 lb/ acre), and tebuthiuron (Spike) pellets were also shown to be an effective control method.

Buffelgrass (*Cenchrus ciliaris*)

Buffelgrass, a mat-forming, perennial grass native to Africa and Asia, has been naturalized on Hawai`i Island since the 1930s, and today it is common in disturbed, dry lowlands of most of the main Hawaiian Islands (Wagner *et al.* 1990). At Pu`uhonua o Hōnaunau NHP, buffelgrass was found at only one locality in 1992-94; this small patch, perhaps only one individual plant, was growing on transect 2 between the 1871 Trail and the coast (Pratt and Abbott 1996a). By 1998, buffelgrass appeared to have been eradicated from the Park after it was treated with Roundup (Victor Bio, pers. comm 1998) and additional plants could not be found in the vicinity (Pratt 1998a). This grass was recognized as a potential fire hazard in the previous botanical survey of the Park (Smith *et al.* 1986).

Guinea Grass (*Panicum maximum*)

Guinea grass is a large perennial bunchgrass with wide leaves and a large, spreading panicle of tiny flowers. Guinea grass is native to Africa and was introduced to Hawai`i as a forage grass (Wagner *et al.* 1990); this grass probably invaded the Park from the adjacent ranch, where it is a desirable forage species. Guinea grass has demonstrated its ability to form a dense ground cover beneath *ēkoa* trees and cover up archaeological features; it is clearly a pest species at Pu`uhonua o Hōnaunau and has the potential to become a serious pest at Kaloko-Honokōhau NHP and Pu`ukoholā Heiau NHS. In the 1992-94 survey of Pu`uhonua o Hōnaunau NHP, Guinea grass was found to be the dominant ground cover in the southern part of the Park between *Alahaka Pali* and the southern boundary, and a few scattered plants were observed between the coast and the 1871 Trail just north of the *pali*. One dense patch of the grass was seen near the coastal trail just north of the old salt vat (on transect 2) (Pratt and Abbott 1996a). Additionally, Guinea grass plants were observed in the northeastern corner of the Park along the road to the sewage treatment plant and on the upper tenceline. Guinea grass was also noted near the sewage plant in the 1986 botanical survey (Smith *et*

*al.*1986), but the dense infestation in the southern part of the Park was not mentioned. The grass was likely present in 1986 within the *ēkoa* shrubland south of *Alahaka*, but this relatively undeveloped area was not extensively searched in the earlier survey.

It is not feasible to remove Guinea grass from the Park, but a strategy of containment to the southern part of the Park is logical. This grass is a potential fire hazard and an obvious invader of archaeological sites, and it should be prevented from becoming more widely established within the northern half of the Park. It is recommended that Guinea grass be treated with herbicide and removed where it currently occurs near the sewage treatment site and old road in the northeastern corner of the Park. The few sites infested by Guinea grass behind the current administration buildings should also be treated and removed. Elsewhere the grass has been treated with a foliar spray of a dilute solution of Roundup or Rodeo. The same treatment that has been used effectively against the grass along the 1871 Trail in *Ki`ilae* Village should also work at sites in the northern half of the Park.

Other Localized Alien Plant Species

Before the removal of the former Superintendent's house, there were at least 20 alien ornamental plants in the surrounding yard. When the house was demolished in 1997, many of the ornamental plants were removed. Alien species removed from the house yard include: globe amaranth (*Gomphrena globosa*), pineapple (*Ananas comosus*), wandering jew (*Tradescantia zebrina*), panax, hibiscus, pothos, and Barbados lily. These seven species were not found at any other Park localities in the past two botanical surveys, so removal from the former Superintendent's house yard was also eradication from the Park. Several species that remained at the site in January 1998 should also be removed; these alien ornamentals are inappropriate to the cultural and historic scene of the Park: pomegranate (*Punica granatum*), oyster plant (*Tradescantia spathacea*), money tree, bougainvillea, bowstring hemp, papaya, plumeria , and mixed succulent plants including baby sun rose, agave, jade tree, aloe, and a succulent of unknown species (*Echeveria* sp. or *Kalanchoë pumila). Loulu* and *hala* trees planted at the site of the former house should be allowed to remain.

A few native plants and useful aliens have been planted at the current administration and maintenance buildings. The native *hala* and *`a`ali`i* should not be harmed, as they are appropriate to the area. The few non-native plants occurring adjacent to the buildings, such as aloe, are relatively innocuous and may be left in place until the temporary building are removed.

While the earlier botanical survey noted a number of alien ornamental plants in the developed area near the Visitor Center and the Great Wall (Smith *et al.* 1986), few of these remained in 1998. They have probably been removed by Park staff as inappropriate plants over the last 10 years. Alien plants noted in 1986 that are no longer extant in the Park include *pīkake*, sea island cotton, coffee (*Coffea arabica*), *pua kenikeni*, and sea grape. A few inappropriate alien ornamentals remain near the Visitor Center, such as Madagascar olive, spider lily (*Crinum* sp.), and the recently established gold fern (*Pityrogramma austroamericana*). These species do not represent a serious threat to the Park's resources, but should eventually be removed in the interest of restoring the historical scene. Mechanical removal will probably suffice for spider lily and gold fern, but the two Madagascar olive trees may require a cut-stump application of herbicide.

Other very localized alien plants growing near the Visitor Center that could be eliminated from the Park with relative ease are date palm, found near the shore just south of the picnic area; false daisy (*Eclipta alba*) near the brackish ponds; and khaki weed (*Alternanthera pungens*), scattered along trails between the Visitor Center and the *Pu`uhonua.* Date palm is a potential threat to rock walls of archaeological sites, and khaki weed may become an invasive plant, as it has done on Maui (Steve Anderson, pers. comm. 1996).

Monitoring and Research Needs

Pili Grass Restoration using Fire as a Management Tool

Pili grass was probably more common before the invasion of alien shrubs in the 19th and 20th centuries. Residents of the area reported that the vegetation of *Hōnaunau* was formerly more open and that *pili* grass was prominent (National Park Service 1976; Bryan and Emory 1986). By the 1950s, alien shrubs covered the area later to become the Park, and *pili* was not a noticeable component of the vegetation (Greenwell 1986). By the time of the botanical survey of 1992-94, naturally-occurring *pili* was restricted to a few remnant patches in the northeastern part of the Park; these patches of grass were restricted to rocky outcroppings in the eastern, upland section of the Park between the 1871 Trail and the boundary fence. The species was also found in the median strip of the Visitor Center parking lot, where it had been earlier sown by Park staff (Pratt and Abbott 1996a).

Pili is maintained in the strip adjacent to the Visitor Center parking lot by weeding and periodic re-sowing of seeds. Park staff members use the planted *pili* to interpret Hawaiian cultural uses of native plants. The beds also serve an ornamental function; native and Polynesian tree species (*loulu, kamani*, coconut palm, *noni*) have also been planted here. Park maintenance workers would like to find a method to intensify the cover of *pili* at the site of planting, so that bare ground is eliminated and the need to weed alien herbs is reduced. In January 1998, the Hawaii Volcanoes National Park Fire Management Officer and staff carried out an experimental burn in a section of the Visitor Center parking lot median strip to investigate the use of prescribed fire as a management tool for *pili* grass. If successful in stimulating *pili* and reducing the cover and abundance of alien plants, fire might be considered as a tool to encourage *pili* growth elsewhere in the Park. The ground cover of burned and unburned adjacent areas was measured before the experimental burn and at both two weeks and four months after the fire to assess the relative cover of *pili* and other plant species (Pratt 1998b).

Several trends were noted in the burned area four months post-burn. *Pili* grass survived the fire and resprouted at clump bases; *pili* also recovered from seedling recruitment. After four months *pili* cover (28.3%) was still less than half its pre-burn percentage (64.4%). The other common grass present in the burned area, Natal redtop, decreased from 6.6 to 1.7% after the fire and did not quickly recover. A few other weedy species were decreased in cover by the fire, most notably passion flower and blue-seeded portulaca. Passion flower vines quickly recovered and were seen growing the burned area immediately after the fire. Nonetheless, passion flower cover decreased to 7.5% along the transects after the fire from its pre-burn cover of 11.7%. Litter, detached dead material, increased from 2.5 to 28.3% after the fire, and bare soil went from 0 to 11.7%. Rocks were also exposed by the fire.

By contrast, in the unburned control area adjacent to the burn site, the cover of *pili* held steady (58.9 to 52.4%), and the alien redtop grass increased from 14.1 to 21.6% cover. The cover of dry, dead litter material almost doubled in the control area (from 5.9 to 10.3%) leading to unsightly conditions in this highly visible area near the Visitor Center. The results of this experimental burn are not clear-cut. While the fire reduced the cover of alien herbs and cleaned up the dead litter material by reducing it to ashes, the recovery of *pili* grass was slower than expected, and bare ground remained exposed four months after the fire. Additional monitoring should be carried out 8 and 12 months post-burn to fully evaluate *pili* recovery.

While fire may not be the desired technique to use in a highly visible site such as the parking lot, prescribed fire may have some use in the experimental restoration of *pili* grass and reduction of redtop at other sites in the Park. Several additional strategies of pre- and post-fire *pili* seed sowing should be tried to enhance the spread and eventual ground cover of the native *pili* grass. Results from ongoing research at Pu`ukoholā Heiau NHS (Daehler 1997) may be useful in helping managers plan strategies for *pili* restoration. Naturally, great care would have to be taken to prevent fire from getting out of control at any Park sites chosen for future

experimental burns. Hand-pulling of alien grasses has been shown to be effective at reducing competition and allowing *pili* to increase at experimental sites in Kaloko-Honokōhau NHP (Pratt *et al.* in prep.) While time consuming and possible in only a small area, the manual control method has the advantage of usefulness at sites in which fire could not be used because of safety concerns.

Alien Plant Control Methods Research

At present, Roundup (glyphosate) and Garlon (triclopyr) are the only herbicides used to treat alien plants within Pu`uhonua o Hōnaunau NHP. Roundup is widely used in Hawai`i as a general control for herbaceous weeds, and it is also effective on a few woody plants. Garlon is designed for use against woody plants, and different formulations are mixed with either water or oil-based carriers. With the exception of Guinea grass and redtop and the potential for reinvasion by fountain grass, most of the serious alien plant problems in Pu`uhonua o Hōnaunau involve invasive shrubs and trees (Table 1).

Several alien plants that have been sparingly planted or have become established on their own are inappropriate to the historical scene within the Park; these species are not widely considered problems, and there is little known about effective chemical control methods for them. Examples of these localized alien plants often considered to be ornamental species in other settings are autograph plant, Madagascar olive, and spider lily. The best strategy for such localized alien ornamental plants is removal by the most practical method, either mechanical or application of a broad-spectrum herbicide. It is probably not worthwhile to conduct treatment research on such uncommon alien plants.

Table 1. Invasive Alien Plant Species of Pu`uhonua o Hōnaunau National Historical Park

Scientific name	Common name	Current Abundance
Acacia farnesiana	*Klu*	Common in shrublands
Batis maritima	Pickleweed	Eliminated from Park ponds, potentially invasive*
Clusia rosea	Autograph tree	Eliminated from Park, potentially invasive*
Ficus microcarpa	Chinese banyan	Eliminated from Park, potentially invasive*
Lantana camara	Lantana	Common in shrublands
Leucaena leucocephala	*Ēkoa, haole koa*	Abundant in shrublands
Melinis repens	Natal red top	Abundant in northern Park
Opuntia ficus-indica	Prickly pear cactus	Rare, potentially invasive
Panicum maximum	Guinea grass	Abundant in southern Park
Pithecellobium dulce	*`Opiuma*	Common
Prosopis pallida	*Kiawe*	Occasional near coast
Schinus terebinthifolius	Christmas berry	Common in northern Park

* Removed from Pu`uhonua o Hōnaunau NHP in 1996-98.

One of the most abundant and highly invasive alien plant species in Pu`uhonua o Hōnaunau NHP, *ēkoa* or *haole koa*, has proven very difficult to control in other natural areas in Hawai`i, such as Hawaii Volcanoes National Park (Tunison *et al.* 1992), where Park-wide control was abandoned and efforts are now directed only to Special Ecological Areas (Tunison 1992). While Hawaii Volcanoes National Park currently

uses a solution of 5% Garlon 4 in diesel as a basal bark treatment for this shrub, the treatment is not completely effective in the coastal lowlands. Research by Motooka (1993) indicated that a basal bark application of triclopyr ester (Garlon 4) or 2, 4-D diluted to 2% product in diesel are both effective at killing *ēkoa*. Past control efforts in Hawaii Volcanoes National Park used Tordon 10K pellets or a foliar application of 5% Roundup; neither method was effective. Several herbicide tests were carried out on *ēkoa* in the 1980s. A test of four different concentrations of Garlon 4 in diesel (0.5%, 2.0%, 5.0%, and 10%) applied to the basal bark of *ēkoa* demonstrated that all treatments caused defoliation, but resprouts appeared in most plots after 11 months (Kageler 1983). Eldredge and Gardner (1984) tested seven concentrations of Garlon 4 in water on cut stumps of *ēkoa* at Pu`uhonua o Hōnaunau NHP. Early results indicated that only the 10% solution of herbicide showed promise. Gardner (1985) reported on tests carried out in Mānoa Valley and on a nearby dry ridge on O`ahu. After six months, the most promising cut-stump treatments were 4% Garlon 4 in diesel, 25% Roundup in diesel, 5% Garlon 4 in water, 20% Garlon 4 in water, undiluted Brush-B-Gon (Garlon 3A premixed at 8%), and undiluted Roundup. Basal bark treatments were less successful, particularly at the wet site, but at the dry site, Garlon 4 at 4% in diesel, as well as 25% Roundup in diesel prevented resprouting for the first six months.

Motooka (1988) found that Picloram (Tordon) was effective when applied to a notch on *ēkoa;* later he found that Tebuthiuron (Spike) pellets at 10 lb/acre (2 lb/acre active ingredient) gave adequate control along *Haleakalā* Highway on Maui (Motooka 1995). Tordon may no longer be used in the National Parks, and soil treatments, such as Spike, are probably not desirable at near-coastal sites within Pu`uhonua o Hōnaunau NHP. Small-scale research on effective herbicides and application methods should be initiated at Pu`uhonua o Hōnaunau NHP to define the most effective methods to treat *ēkoa* under the specific conditions found at *Hōnaunau*. Based on previous herbicide methods research, the most promising herbicide for use against *ēkoa* is Garlon 4; both cut-stump and basal bark application techniques should be tested.

Apart from *ēkoa*, the three most invasive alien shrub species of Pu`uhonua o Hōnaunau NHP are *klu*, *`opiuma*, and Christmas berry (Pratt and Abbott 1996a). All three are widespread and relatively abundant in the Park north of *Alahaka Pali; `opiuma* is also found in the southern third of the Park. *Klu* has not been controlled at other Parks on Hawai`i Island, but the results of several research projects are available. Motooka (1993) achieved complete control using triclopyr ester (Garlon 4) diluted to 2% in diesel, applied as a basal bark treatment to *klu* plants approximately 5 cm (2 in.) in diameter. This study was carried out on Moloka`i. Motooka (1991) also found that *klu* was sensitive to triclopyr (Garlon) as a foliar spray; 0.5 kg/ha resulted in adequate to good control with different surfactants. This method of application is probably not as useful as the basal bark method, except where other desirable plants do not occur nearby. Since herbicide research has indicated that Garlon 4 is effective against *klu*, small-scale herbicide testing should be carried out on *klu* at Pu`uhonua o Hōnaunau NHP to find the lowest effective herbicide concentration and the most useful application method. It is desirable to find one treatment that will be effective against a group of alien shrub species that grow mixed together at many Park sites where vegetation management is a priority.

`Opiuma* is currently being controlled successfully at Kaloko-Honokōhau NHP by the cut-stump application of the herbicide Roundup (Laura Schuster, pers. comm. 1998). Motooka (1995) determined that *`opiuma was sensitive to 2% triclopyr (Garlon) used as a high volume basal bark application; a kill rate of 70% was achieved in a trial at *Napo`opo`o*. In a separate trial along roadsides, Motooka reported an injury rating to *`opiuma* of 100 (complete control) with Tebuthiuron (Spike) applied at the rate of 10 lb/acre.

Christmas berry is widely recognized as an invasive alien species, and control efforts and herbicide research have been carried out in Florida, where the shrub (known as Brazilian pepper tree) is a serious pest in and near the Everglades. In a thorough study of the effectiveness of 14 herbicides for use against Christmas berry in Florida, Ewel *et al.* 1982 recommended triclopyr (Garlon 4) applied as a basal bark spray (5 ml/liter diesel) or glyphosate (Roundup) applied as a foliar spray (17 ml/liter water). The long-lasting herbicide Velpar was also deemed effective against Christmas berry, but it also killed all surrounding plant

species. Following the Everglades study, the University of Florida Cooperative Extension Service (1990) recommended Garlon 4 diluted to a 2-25% solution in diesel as a basal bark treatment or Garlon 3A diluted 1:1 (50%) in water as either a cut-stump or frill application on Christmas berry. In Hawai`i, Hawaii Volcanoes NP has effectively used 5% Garlon 4 in diesel as a basal bark treatment to treat Christmas berry (Chris Zimmer, pers. comm. 1997). Motooka (1991) noted good weed control (>90% defoliation) of Christmas berry sprayed with triclopyr (probably Garlon 3A as Redeem) at three different rates 1 kg/ha, 2 kg/ha, and 4 kg/ha. Christmas berry was far less sensitive to the herbicide metsulfuron applied to the foliage, and its response to the application of the granular soil sterilant tebuthiuron varied from inadequate to good, depending on the rate of herbicide applied (2.1 to 4 kg/ha). Based on previous research, Garlon 4 and Roundup should be tested for use against Christmas berry at Pu`uhonua o Hōnaunau NHP. Cut-stump and basal bark application methods are likely to be most useful at the Park, as they direct herbicide more specifically to target weeds that does a foliar spray.

Lantana has been suggested as a weed deserving of control efforts at Pu`uhonua o Hōnaunau NHP (Smith *et al.* 1986), but this low-growing shrub was recently found to be less widespread and abundant than the four species discussed above (Pratt and Abbott 1996a). Additionally, the many biocontrol agents that have established after being introduced to Hawai`i to combat lantana have weakened it and reduced its ability to spread and intensify in many areas (Davis *et al.* 1992). Should herbicides be required for use against lantana, Motooka (1995) found that a basal bark application of 2% 2,4-D provided good to complete control, and 2% triclopyr in diesel was somewhat less effective. A previous trial showed triclopyr ester to be more effective at killing lantana than was 2,4-D (Motooka 1993). The herbicide metsulfuron applied as a foliar spray was reported to be moderately effective at reducing the cover of lantana; there was variation among treatments with different herbicide rates and different surfactants (Motooka 1993).

Sourbush is not widespread at Pu`uhonua o Hōnaunau NHP and is not currently threatening the brackish pool resources of the Park. However, if the shrub becomes more common or invades the Park's pools, a low-level of testing may be required to find an effective herbicide suitable for use in and near the aquatic environment of the pools. Hawaii Volcanoes National Park has had success controlling this species using two different treatments: 1% Roundup as a foliar application or Garlon 3A 10% as a stump treatment (Chris Zimmer, pers. comm. 1997). Motooka (1995) reported complete control of sourbush using either glyphosate (Roundup) at 1.5 lb/acre or triclopyr (Redeem or Remedy) at 1 lb/acre. Because of the success of Roundup in other studies, the closely related aquatic herbicide Rodeo should be tested for use against sourbush, if the plant invades the pools or increases its range and moves closer to the Park's pools.

The most abundant grasses in the Park today are Guinea grass and Natal redtop. Both species cover sizeable portions of the Park; Guinea grass is the dominant ground cover in the southern reaches of the Park beyond *Alahaka Pali*, and redtop is most abundant in open areas near the 1871 Trail between the *Pu`uhonua* and *Alahaka* (Pratt and Abbott 1996a). At present, Guinea grass is controlled along the southern part of the 1871 Trail, using a dilute solution of Roundup (Victor Bio, pers. comm. 1997). As it is unlikely that large portions of the *ēkoa*/Guinea grass forest/shrubland will be managed in the near future, there is probably no immediate need for further herbicide research on Guinea grass. The method currently used by Park staff has been successful at clearing Guinea grass from the side of the trail, and will likely suffice for future control at sites in the northern part of the Park near the existing sewage treatment facility. Redtop grass is not specifically controlled at any managed sites in the Park, but this grass will likely be killed by a dilute solution of Roundup in water. If large expanses of redtop must be treated, Roundup should be tried first, and the sprayed sites should be evaluated for herbicide effectiveness. Such simple monitoring with a rating system for plant response to herbicide or a measurement of cover before and after treatment will be valuable for directing future vegetation management at sites dominated by Natal redtop grass.

Potential Use of Fire for Vegetation Management

The experimental use of fire to manage *pili* in a highly visible site is described above; the goal for the research burn was to learn if fire could be used to intensify *pili* grass cover, reduce alien plant cover, and clean-up unsightly grass litter. Results from the preliminary evaluation of fire effects on pili and other plants in the parking lot burn suggest that fire is a possible tool for converting Natal redtop grasslands to *pili* at less visible, undeveloped sites in the Park. If such a project could be demonstrated, areas along the 1871 Trail now dominated by redtop grass and scattered alien shrubs could be converted to the native *pili* grass, small parcel by small parcel. Such a prescribed fire would have to be planned very carefully to prevent the fire from escaping beyond a small well-defined area. The lack of natural fuel breaks at Pu`uhonua o Hōnaunau NHP (other than the ocean and possibly *Alahaka Pali*) will make standby firefighters and suppression equipment, such as hose lays, a necessary part of any proposed experimental burn. In Hawaii Volcanoes National Park, prescribed fires in protected *kīpuka* of the coastal lowlands led to replacement of Natal redtop grass by the fire-resistant native *pili,* when both species were present before the fire. Redtop grass appears to be easily killed and its cover reduced greatly by fire, at least over the short term. However, redtop will not burn when green, so conditions must be very dry for such an experimental burn to be successful. Also, maintenance of *pili* grass may require repeated fires (Tim Tunison, pers. comm 1998). There is probably little potential use for fire as a management tool to reduce most of the invasive alien species in the Park. Apart from Natal redtop and Guinea grass, most of the invasive alien plants in the Park are shrub species known to survive fire and resprout from the base. Smith (1985) reported that *ēkoa*, lantana, *`opiuma*, and *klu* are all capable of regenerating rapidly following fire, primarily by resprouting from basal shoots. Among the most invasive shrubby species of the Park, only *kiawe* is likely to be killed by intense fire. No alien plant control through the use of fire should be initiated without a long-term plan for follow-up management.

Kaloko-Honokōhau National Historical Park

Introduction

Kaloko-Honokōhau National Historical Park (NHP) is located on the western shore of Hawai`i Island within the District of North Kona. The Park is 6 km (3.6 miles) north of the city of *Kailua-Kona* and is partly surrounded on two sides by commercial development; *Honokōhau* Harbor is directly south of the Park, and *Kaloko* Light Industrial Park is adjacent on the east, directly across the Queen *Ka`ahumanu* Highway. The Park extends from the Highway to the coast, and includes more than 243 ha (600 a) in the coastal portions of two *ahupua`a* or Hawaiian land divisions: *Kaloko* and *Honokōhau*. Directly north of Kaloko-Honokōhau is *Kohanaiki ahupua`a*, currently unoccupied but the site of a proposed resort development. The Pacific Ocean is the western boundary of the Park, but the authorized boundaries include off-shore waters of *Honokōhau* Bay that are currently managed by the State of Hawai`i. The Park is in a warm and dry climate zone characterized by seasonal (summer) rains and a pronounced diurnal wind pattern of land and sea breezes (Blumenstock and Price 1967). The mean annual rainfall at a weather station at the nearby old *Kona* Airport is 616 mm (24.3 in.) (Giambelluca *et al.* 1986). Kaloko-Honokōhau NHP (or KAHO) is on the coastal plain of the currently inactive *Hualālai* Volcano, and the lavas making up the substrates of the Park have been placed in three different age groups (Moore *et al.* 1987). Most of the Park is covered by lava 3,000-5,000 years old, but the areas around *Kaloko* and *`Aimakapā* Ponds are estimated to be 5,000 to 10,000 years old. The youngest substrate is a sparsely vegetated *`a`ā* flow in the center of the Park, estimated to be 1,000-3,000 years old (Fig. 4). Much of the Park has no significant soil cover, but an extremely rocky peat soil was mapped in an area northeast of *Kaloko* Pond (Sato *et al.* 1973), and Canfield (1990) recognized organic muck soils in marshes near the two large fishponds.

Legal Mandate

In 1972, the U. S. Congress declared that *Honokōhau*, which had been earlier designated a National Historical Monument, encompassed nationally significant cultural, historical, and archaeological resources worth preserving (National Park Service 1994b). Congress authorized the formation of a *Honokōhau* Study Advisory Commission composed primarily of native Hawaiians; this commission prepared a study and submitted it to Congress in 1974 (*Honokōhau* Study Advisory Commission 1974). In 1978, the U. S. Congress authorized the formation of Kaloko-Honokōhau National Historical Park "...to provide a center for the preservation, interpretation, and perpetuation of traditional native Hawaiian activities and culture, and to demonstrate historic land use patterns, as well as to provide a needed resource for the education, enjoyment, and appreciation of such traditional native Hawaiian activities and culture by local residents and visitors..." (National Park Service 1994b). No specific time period is designated as the goal for the Park's interpretive and restoration activities, but the emphasis on Hawaiian culture indicates that the period of Hawaiian inhabitation is the time period most desired for recreation of a cultural landscape. The late prehistoric period to the early 1800s is broadly the goal for restoration of a cultural landscape within the Park, although later historic periods will also be subjects of Park interpretation.

Early History and Vegetation

The *Kaloko* coastline was probably settled by Hawaiians by 900-1,000 AD, and large cohesive settlements were in place by the 1200s (Greene 1993; Cordy *et al.* 1991). The fishponds that are the most prominent features of the Park were developed later, perhaps in 1500-1600 AD. By the early historic period, both *Kaloko* and *Honokōhau* were well populated and the vegetation of the area was likely much changed from the original plant cover. Great cultural changes occurred in the middle of the 19th century resulting in depopulation of much of coastal *Kaloko*, and by the 1900s, much of the area was used to graze cattle.

A number of native strand and marsh plants persist today in the Park, but these probably represent a fraction of the number of species formerly present. A few native shrub and tree species remain scattered throughout the Park, most notably *pua pilo* or *maiapilo* (*Capparis sandwichiana*), *alahe`e* (*Canthium odoratum* or *Psydrax odorata*), *naio* (*Myoporum sandwicense*), *`a`ali`i* (*Dodonaea viscosa*), *`ilima* (*Sida fallax*), *`uhaloa* (*Waltheria indica*), and *ko`oko`olau* (*Bidens micrantha* subsp. *ctenophylla*). Original pre-human vegetation was probably dry forest and shrubland, and it likely contained some of the species still extant on rough *`a`ā* just upslope of the Park. Possible components of original forest and woodland now missing from the Park but found upslope are *`ōhi`a lehua* (*Metrosideros polymorpha*), *lama* (*Diospyros sandwicensis*, and *`ohe makai* (*Reynoldsia sandwicensis*); rare species, such as *hala pepe* (*Pleomele hawaiiensis*) and *Neraudia ovata,* may also have ranged into the area now within the Park. Polynesian introductions and native plants useful to Hawaiians were likely prominent components of coastal and lowland vegetation of the early historic period.

A recent analysis of the pollen record at *`Aimakapā* Pond provided evidence that several native plant species not currently found within the Park were growing near the pond during the period prior to European contact (Douglas and Hotchkiss 1998). Native shrub and tree species that contributed pollen to the pond sediments before the historic period, but are no longer found on site include *`aweoweo* (*Chenopodium oahuense)*, *`akoko* (*Chamaesyce* sp.), *kolea* (*Myrsine* sp.), *`ohe makai*, *`ōhi`a lehua*, *lama*, and a *Pipturus* type that may represent *Neraudia ovata*. As these are all dry forest or shrubland species, and several of them are extant within 3 km (2 miles) of the pond, these species should be considered for reintroduction to the Park. One of the most significant discoveries of the pollen analysis at the Park was that *loulu* palm (*Pritchardia* sp.) was a component of the pollen record at *`Aimakapā* from early times into the modern period. This endemic species was apparently a recent loss from Kaloko-Honokōhau NHP.

Existing Vegetation

Recent surveys of vegetation within Kaloko-Honokōhau have found that most of the Park is covered by communities dominated by alien plants (Canfield 1990; Pratt and Abbott 1996b) (Fig. 5). The coastal strand and wetlands around the two large fishponds support vegetation in which native and Polynesian species are still prominent. A forest of closed *kiawe* (*Prosopis pallida*) forms a distinct band inland from the coastal strand and around *Kaloko* and *`Aimakapā* Fishponds. Elsewhere in the Park *pāhoehoe* substrates are covered by a mixed fountain grass (*Pennisetum setaceum*) and shrub vegetation in which *ēkoa* (*Leucaena leucocephala*) is often dominant, but several other alien shrubs also have significant cover. The most recent *`a`ā* flow in the center of the Park is almost bare of vegetation, and the 3,000-5,000 year old flow in the northern and central part of the Park is also sparsely vegetated. Despite the dominance of alien plants in the vegetation of Kaloko-Honokōhau NHP, 32 native (primarily indigenous) plant species and four Polynesian introductions were noted on the most recent plant survey (Pratt and Abbott 1996b).

Primary Resources and Resource Zones

The most significant resources of the Park are the two large fishponds of *Kaloko* and *`Aimakapā*; these ponds have great value as both cultural/archaeological and natural resources. Broad semicircular bands around both of the two large fishponds are considered to be significant cultural resources, and the remainder of the Park is called a resource area in which cultural resources are limited or less well known. In the Park's General Management Plan (GMP), most of the Park is mapped as a historic preservation sub-zone; the coastline is considered to be a natural environment; and the two large fishponds are considered to deserve preservation for both natural and historic values (National Park Service 1994b) (Fig. 6).

Strategies of Vegetation Management at Kaloko-Honokōhau NHP

Alien Plant Control

The vegetation cover of Kaloko-Honokōhau NHP is currently dominated by alien plant species, particularly fountain grass and *ēkoa*. Despite this alien plant dominance, the Park supports at least 32 native plant species, as well as Polynesian introductions, which together comprise 30% of the flora (Pratt and Abbott 1996b). The Park's native sedge-dominated marshes continue to support mainly native species and are among the best wetlands remaining in the State. Because the time period for which the Park would like to recreate a cultural scene is the late prehistoric and early post-European contact period, the desired vegetation cover of the Park (at least in heavily visited areas) should be composed primarily of native and Polynesian plant species. Obviously, the restoration of such a vegetation Park-wide will be a very arduous undertaking, although the native and Polynesian tree and shrub species extant in the Park will make the task more feasible in certain sites. It is at these sites of native plant assemblages, as well as other priority sites for management, that alien plant control and native plant restoration should be focused. Several of the prioritysites are existing or proposed trails. Those trails used by visitors that pass through flammable vegetation, particularly fountain grass, should be a focus of alien plant control in the interest of hazard fuel reduction. If the trails were centered in a corridor where alien grasses and other fuels were removed, the trails would function as safety zones for visitors, in case of wildfire in the Park.

In addition to controlling alien plants at priority sites, particularly noxious or invasive plant species should be controlled Park-wide, if this is feasible. Park-wide control or elimination is most possible for those alien species that are recent invaders or are highly localized (Appendix A). The highest priority for eradication should be species like ivy gourd (*Coccinia grandis*), which are known to be highly invasive and disruptive elsewhere on the island. Ivy gourd was first noted in the Park in the early 1990s and is still relatively localized, although it is spreading rapidly. Other examples of invasive alien plants currently restricted to small infestations in the Park are buffelgrass (*Cenchrus ciliaris*), Molasses grass (*Melinis minutiflora*), and silver or silk oak (*Grevillea robusta*). Many other alien plants have localized distributions in the Park, but most of these do not represent a serious threat to either archaeological resources or natural systems. Such innocuous species should not be the focus of Park management efforts. The criteria for a Park-wide control effort to remove a plant species should be invasive behavior elsewhere and a localized distribution allowing eradication from the Park.

New alien plant species should be prevented from establishing in the Park; prevention requires the periodic searching of roadsides, trails and other likely points of entry for invaders. A search of roads, trails, and boundaries, carried out once or twice a year (quarterly, if possible), would be a valuable management tool to prevent new weeds from infesting the Park (Tunison and Zimmer 1992). Such a monitoring program requires one individual knowledgeable about the alien plants already in the Park and capable of recognizing uncommon alien plants. Results of such a monitoring program should become part of the Park files and be described in an annual report.

The Park should have an Integrated Pest Management (IPM) plan that reviews control methods used for alien plants (and other pests) within the Park. This plan, as well as the Resources Management Plan, will benefit from inclusion of a priority list of alien plant species to be treated or controlled within the Park. The most important sites for vegetation management should also be listed with designation of high, medium, and low priority given for each site to be managed. Categories of alien plants to be considered in the priority list are species to be controlled only in priority sites; localized alien plants to be eliminated or controlled throughout the Park; invasive alien species to search for on roads, trails, and other points of entry; and ornamental or crop species to be removed where they have been inappropriately planted. Within each category, alien species should be prioritized for urgency of action.

Herbicide use is inevitable, given the severity of the alien plant infestations within the Park. Manual and cultural control methods should be used whenever possible, but effective control of many weeds will require the use of herbicides. Because herbicide use is sometimes a controversial issue, great care should be exercised with herbicides and other chemical control tools within the Park. Because of the extent and importance of the wetlands surrounding the major fishponds and the presence of scattered anchialine pools throughout the Park, wetland vegetation management will be particularly complex. Caution should be exercised when using herbicides near wetlands, and only herbicides approved for use in and near wetlands should be applied to weeds in these areas. Park personnel applying herbicides should have adequate training, and label restrictions should be followed at all times. The current system of herbicide use approval and annual chemical use reporting should be continued.

Native Plant Management and Restoration

General strategies for native plant management and restoration. - Most of the land area of Kaloko-Honokōhau NHP has been designated as an historic preservation zone, and the two major fishponds of the Park have been recognized as both natural and historic preservation zones. The offshore waters and areas surrounding anchialine pools are considered to be natural environment zones (National Park Service 1994b). Very little area within the Park has been proposed for modern or traditional developments. Because different types of management zones are recognized for different portions of the park, the specific goals of native plant management and restoration may vary slightly with the site. However, overall vegetation management should be compatible with maintaining an historic scene of the early 1800s, with emphasis on maintaining or restoring elements of vegetation that are appropriate to that time period. The areas around the fishponds and anchialine pools, should be kept in as natural a condition as possible. Even in the modern development zone, there is probably no need to intentionally use alien plants (National Park Service 1988); native and Polynesian plants already in the Park or likely to have grown there during the early 1800s are more appropriate for use in landscaping. The selection of Polynesian versus native plant species to maintain at sites or to use in restoration should be made on a site-by-site basis. In the following discussion of native plant management, Polynesian plant species may be considered to have the same status as native plants at most of the priority sites in the Park; the only exception is those sites valued primarily for natural rather than cultural and historic features.

The primary task of restoring the historic scene to most of the Park involves the removal of alien plant species that arrived in the Hawaiian Islands and invaded the area of the Park long after the early historic period. Because most of the Park is dominated by these alien plant species, the goal of total eradication of aliens is not feasible, and the focus of alien plant removal and native or Polynesian plant restoration should be the priority sites for vegetation management discussed in the next section. The duality of alien plant control and native plant restoration is recognized by both the General Management Plan (National Park Service 1994b) and the Resources Management Plan (National Park Service 1996b) of Kaloko-Honokōhau NHP.

Because it is the largest of the three National Historical Parks of *Kona* and retains the greatest native plant cover, Kaloko-Honokōhau NHP has the best chance of success for restoration of native and Polynesian vegetation to a semblance of the historical scene of the early 1800s. Since the time period to be illustrated in the historical scene is relatively broad and the Park's land area is greater than 243 ha (600 a), there are many possibilities for plant restoration or augmentation, and a greater variety of structural vegetation types appropriate to the Park: coastal vegetation, marsh, lowland dry forest and shrubland, cultivated plant assemblages, groves of native and Polynesian trees, and individual plantings likely to be found around Hawaiian habitations.

Criteria to use in the selection of plant species to reintroduce or restore to priority sites within the Park are: status as natives or Polynesian introductions, appropriateness to the outplanting site, and value to enhancement and interpretation of the historic scene. Native and Polynesian species should be used

exclusively for outplanting, as it is inappropriate to introduce alien plants to a natural, cultural, or historic zone where they do not belong (National Park Service 1988). Revegetation attempts should use plants present at the time of the historic or cultural scene to be restored (National Park Service 1993a). Use of species appropriate to the outplanting site will vary with the priority sites within the Park; some sites that were naturally bare or were intensively developed for Hawaiian use will not require any outplanting, while other sites will call for revegetation with assemblages of native plants. Some areas may be allowed to recover native plant species on their own; coastal strand vegetation often has this ability. In general, native and Polynesian species to be planted in the Park should be lowland or coastal species capable of living in a dry area with little soil. Species that are restricted to the uplands or wet forest habitats probably have no place within the Park, even though several wet forest tree species were found in the pollen record of *`Aimakapā* Pond, including *`olapa* (*Cheirodendron trigynum*), *kawa`u* (*Ilex* cf. *anomala*), and *pilo* (*Coprosma* spp.) (Douglas and Hotchkiss 1998). Not all pollen within the pond sediments may be assumed to have been growing on site; wind-borne pollen from upslope forests may have contributed to the lowland pollen record.

It would be best to focus on the restoration of common native and Polynesian species, rather than rare ones, because these are the plants most likely to have been present in the early 1800s and are the plants most likely to succeed as outplantings. However, several rare (and even endangered) plant species may be highly appropriate to coastal sites within the Park, and they should be considered for introduction or re-introduction. Before endangered species are restored to the Park, State Endangered Species permits should be obtained. If any propagation material is to be collected from the wild, the Park should apply for a Federal Endangered Species permit.

Management strategies for existing native plants. - Native plant species comprise 27% of the Park's flora, and Polynesian introductions are another 3% (Pratt and Abbott 1996b). Of the 32 indigenous or endemic plant species found in the Park in 1992-94, more than half are plants of the coastal strand or wetlands. Only three native lowland species are common in the Park; these are *koali`awa* (*Ipomoea indica*), *`ilima*, and the ubiquitous *`uhaloa*. The remaining plants native to the dry lowlands are relatively rare in the Park, including three current or former candidate endangered species: *ko`oko`olau*, *pua pilo*, and the sedge *Fimbristylis hawaiiensis*. Several shrub species that are generally considered common plants in native lowland vegetation are rare to uncommon at Kaloko-Honokōhau NHP; these are *`a`ali`i*, *alahe`e*, *naio*, and *`ili`e`e* (*Plumbago zeylanica*). Four additional herbaceous native plants are also rare in the Park, among them *pili* grass (*Heteropogon contortus*).

The need to conserve these naturally-occurring native plant species in the Park is recognized by several project statements in the Kaloko-Honokōhau Resources Management Plan (National Park Service 1996b). The only intentional disturbance to any of these species warranted in the Park is clearance of archaeological sites or development of trails. Often, native plants can be spared by re-routing trails, and a few native plants may not be unacceptable at many archaeological sites. If necessary, there should be no problem with removing common native plants when they are in the way or are disturbing historical or cultural sites. However, the three rare species extant in the Park should not be molested.

As the Park is new and has no developed sites, other than restrooms and a replica canoe shed, there are no native species plantings around structures. The only inappropriately planted Polynesian species are associated with past dwellings near the *`Ai`ōpio* Fishtrap and *Pu`uoina Heiau*. Those crop species inappropriate to the Park will likely die on their own without special treatment.

Monitoring of native and Polynesian plant species was a goal of the last botanical survey in the Park (Pratt and Abbott 1996b), and parts of that systematic survey may be repeated in the future to determine changes in distribution or abundance of native plants in the Park. However, it will be less time consuming to select certain areas of the Park or certain plants to monitor. At a minimum, the three rare plant species extant in the Park should be periodically remonitored to determine their status. *Pua pilo* shrubs are numerous in the

Park, and this plant is a likely subject for monitoring. A subset of plants should be selected, tagged, measured, and periodically examined for condition and reproduction. The tiny sedge *Fimbristylis hawaiiensis* will also be a easy subject to monitor, as it is concentrated in one general area and may be easily counted. Since few *ko`oko`olau* persist in the Park, this species will also be easy to remonitor by periodic revisits to the few natural and outplanted individuals remaining. General vegetation monitoring for cover and extent of wetland plants will provide information on the dynamics of the important marsh systems in the Park. Likewise, understanding of the composition and extent of the coastal strand will be enhanced by vegetation monitoring along the Park's coastline.

Management strategies for outplantings of native species. - Suggestions for native and Polynesian species to outplant are given in the restoration section of each of the priority sites discussed below. Strategies for outplanting native species in the Park may involve augmentation of the populations of species currently growing in the Park, restoration of native species missing from the Park but documented from the area, or introduction (or re-introduction) of species thought to be appropriate to the coastal and lowland site of the Park. Augmentation and restoration of missing species is more simple to envision and accomplish, because there is no need to justify the outplanting of individuals within the Park. Introduction of native or Polynesian plant species should be proposed only when there is good reason to suppose that the species was present in or near the Park during the prehistoric or early historic period. In general, common native plant species should be the focus of restoration and re-introduction efforts, since they are most likely to survive, and seeds are easier to obtain.

Even with a focus on common native species, rare native plants appropriate to the coast and dry lowlands should also be considered for restoration. Good candidates for introduction or re-introduction include the endangered *loulu* (*Pritchardia affinis*), *`ōhai* (*Sesbania tomentosa*), and *hala pepe*. At least one endangered species appears to be documented in the pollen record of the Park (Douglas and Hotchkiss 1998); the most likely identification of *Pritchardia* pollen found in a core from *`Aimakapā* Pond is *P. affinis*, a listed endangered species native to Hawai`i Island coasts. The absence of *`ōhai* pollen in the recently analyzed pollen record of *`Aimakapā* should not be taken as conclusive evidence that the plant was not growing nearby; pollen of the pea family (Fabaceae) is difficult to identify, and preservation of fossil pollen is variable among species and groups. Endangered plants to be introduced to the Park should be derived from cultivated material. State Endangered Species permits should be obtained prior to outplanting endangered plant species. Other native dry forest species found just upslope of the Park along the *Kaloko* Road should also be considered for outplanting in Kaloko-Honokōhau NHP, including *lama*, *`ohe makai*, and *kolomona* (*Senna gaudichaudii*).

Helpful guidelines for outplanting are found in National Park Service directives (National Park Service 1993a), unpublished reports of other Parks, such as Hawaii Volcanoes NP (Tunison 1996), and in material developed by other agencies (Woolliams and Llop 1993). Specific seed collection guidelines should be developed along with the outplanting program in the Park. In general, seeds should be obtained from the nearest natural source, to take advantage of possible local site adaptations. Seeds should not be collected far in advance of the time they will be sowed or germinated, long-term seed storage often results in loss of viability (National Park Service 1993a). The source of any seed used in Park outplanting programs should be recorded in permanent Park files. Propagation guidelines should also be developed for the Park outplanting program. Plants should not be purchased from commercial nurseries or private growers without proper documentation of the source of the seed and the propagation techniques used. Likewise, plants without documentation should not be accepted as gifts from private individuals. The Amy Greenwell Ethnobotanical Garden should be considered as a site for propagation of native and Polynesian plants for the Park, using seeds collected by Park personnel or designated collectors with the proper technical expertise to identify plants and properly care for seeds. The Garden has a Memorandum of Understanding with the three *Kona* National Historical Parks to accomplish plant propagation work, but extensive use of the Garden may require a more formal arrangement.

Material to be outplanted in the Park should be healthy and free of disease or insect pests (National Park Service 1993a). Plants propagated for the Park should be raised in sterile potting medium from which the upper half inch of soil is removed immediately before outplanting. Plants should be decontaminated with acceptable pesticides at least two weeks before outplanting to remove any plant pests, including nematodes and scale insects. Growth and survivorship of outplanted individuals should be monitored periodically. Records of species outplanted, seed sources, treatment regime, and fate of outplantings should be kept within the Park. Periodic reports of plants restored to the Park and outplanting success should be produced to document the Park's outplanting and restoration program. Similar guidelines for seed collection, propagation, and outplanting have been developed and adopted by Resource Managers at Hawaii Volcanoes National Park (Tunison 1996).

Vegetation Management in Priority Sites

Unlike Pu`uhonua o Hōnaunau NHP, no official list of nationally recognized historic sites exists for Kaloko-Honokōhau. The following 11 priority sites were selected for discussion here because they are either described as sites of historic significance or natural value or they are recognized as potential development sites or managed areas in the recent General Management Plan (National Park Service 1996b). Because it is difficult to rank the importance of these sites, they are not arranged in any priority order in the following sections. Areas that are currently the focus of vegetation management include proposed and new trails, the Māmalahoa Trail, *Kaloko* Fishpond and nearby agricultural features, the environs of *`Aimakapā* Pond, *`Ai`ōpio* and *Pu`uoina Heiau*, and the coastal strip that includes beaches near the major fishponds. All these currently managed areas may be considered high priority sites. When the proposed Visitor Center is constructed, this will obviously become a very high priority site for management. While vegetation management is not currently underway at *Kahinahina`ula* or any of the other anchialine pools, the significance of the natural resources at these sites makes them high priorities for future management. Because all 11 sites seem to warrant management attention, it may be best to leave the detailed prioritization or categorization of priority sites to the managers of the Park.

Proposed Visitor Center and Parking Lot

Description of features and vegetation. - The site proposed for use as a Visitor Center and adjacent parking lot is located in a portion of a relatively recent (1,000-3,000 years) *`a`ā* flow that was bulldozed before the area was acquired as a Park. The Visitor Center site is one of only four modern development subzones proposed for the Park (Fig. 6). Its proximity to the Queen *Ka`ahumanu* Highway, position above the flood zone, and disturbed condition were factors in the selection of this site. The General Management Plan (GMP) for the Park states that the development here will cover 1.6 ha (4 a) and will contain a visitor orientation center, amphitheater, and administration building; the parking lot is planned for the area between the road and the buildings and will be designed with planting islands and walkways (National Park Service 1994b). While the disturbed nature of this site lends itself to development, several reviewers of the draft GMP criticized the site, and the final plan for the buildings has not been developed.

There is very little vegetation at present on this site, except fountain grass invading the disturbed area where bulldozing has created fine material suitable for grass establishment. Elsewhere on the *`a`ā* flow, fountain grass has a cover of <1% and alien shrubs are rarely seen (Pratt and Abbott 1996b). In the adjacent undisturbed part of the flow, the native plants *pua pilo*, *koali`awa*, and *`uhaloa* occur with low frequency; the southern edge of the *`a`ā* flow formerly supported a rare *ko`oko`olau*.

Current or past vegetation management at site. - There has been no management of vegetation by Park Service personnel in this disturbed area.

Vegetation management needed to achieve desired condition. - Once the Visitor Center complex and parking lot have been constructed, much of the bulldozed area will be utilized by the development. Whatever disturbed area remains will probably be impossible to restore, but may perhaps be landscaped. If areas beyond the proposed landscaping remain, it will be desirable to reduce or remove unsightly fountain grass, so that the overall scene on the *`a`ā* is that of a nearly barren substrate with only scattered native plants. Native and Polynesian plants used in landscaping the Visitor Center will enhance its appearance and provide material for education and interpretation (See following paragraphs). Care should be taken during construction to avoid the introduction of new alien plant species on heavy equipment or other vehicles.

Recommendations:

□ Treat fountain grass as needed on disturbed part of *`a`ā* flow near Visitor Center and parking lot (after construction) to maintain an aesthetically pleasing scene.

□ Avoid the introduction of alien plants on equipment and vehicles during construction of the Visitor Center. Monitor the area during and after construction to confirm that such weed introduction has not taken place. Treat any incipient invasion of alien plants found here.

Restoration of native or Polynesian plants. - Several native and Polynesian trees and shrubs already present in the Park have potential as ornamental plantings around the Visitor Center and parking lot. *Hala* (*Pandanus tectorius*) grows at *Ai`ōpio* and on a beach just south of the Park, and *kou* (*Cordia subcordata*) persists near *Kaloko* Pond and *`Ai`ōpio*; these tree species are often used as plantings at lowland sites in Hawai`i. *Hau* (*Hibiscus tiliaceus*) and *milo* (*Thespesia populnea*) are also attractive shrubby trees already present in the Park. The native shrubs *naupaka kahakai* (*Scaevola sericea*), *naio*, *alahe`e*, *`a`ali`i*, and *pua pilo* also have potential as landscape plants (Bornhorst 1996). *Naupaka* is often used in landscaping in *Honolulu* and *Kailua-Kona*.

If herbaceous or ground cover plants are needed for landscaping, the Park contains several attractive native vines, low-growing shrubs, and herbs. Examples are *pōhuehue* or beach morning glory (*Ipomoea pes-caprae* subsp. *brasiliensis*), a coastal vine with large trumpet-shaped pink flowers; *`akulikuli* (*Sesuvium portulacastrum*), a succulent plant with fleshy red-tinged stems and tubular pink flowers found near the shore and around ponds; *`ae`ae* or water hyssop (*Bacopa monnieri*), a white-flowered aquatic herb; and *`ilie`e*, a sprawling shrub with attractive foliage and white flowers borne on upturned spikes .

In a questionnaire sent to a number of the Park's advisors and other interested groups, *loulu* was the plant most often named as appropriate to the proposed Visitor Center and parking lot; the species endemic to the coastal zone of Hawai`i Island, *Pritchardia affinis*, is a logical choice of *loulu* for the Park. More than half of the respondents named *wiliwili* (*Erythrina sandwicensis*) and *noni* (*Morinda citrifolia*) as potential landscaping plants in this area. Other plants suggested by more than one advisor are *lama*, *`ohe makai*, *naio, hala, pua pilo, `a`ali`i, kukui* (*Aleurites moluccana*), and *kī* or *ti* (*Cordyline fruticosa*). While examples of the native trees *wiliwili, lama*, and *`ohe makai* are not present in the Park's current flora, they occur naturally several km upslope, and it may be possible to obtain seeds from nearby areas. All three are very attractive trees well adapted to dry conditions. The Polynesian introductions *kukui* and *kī* would be positive additions to the cultural scene, although water requirements of *kukui* may preclude its use away from the care of the landscaped Visitor Center (Peter Van Dyck, pers. comm. 1997). Potential landscape plants for the Visitor Center named by at least one respondent are *pua kala* (*Argemone glauca*), *`ilie`e, `ilima ku kula* (*Sida fallax*, uncultivated form), *`ūlei* (*Osteomeles anthyllidifolia*), *`ākia* (*Wikstroemia* spp.), *kou, naupaka*, and coconut or *niu* (*Cocos nucifera*).

Recommendations:

□ Select from the above-listed group of native and Polynesian plants already in the Park or appropriate to the area when choosing landscaping plants for the Visitor Center and parking lot.

□ Where possible, collect seeds and propagation material of native plants from within the Park or at the nearest possible natural population. Amy Greenwell Ethnobotanical Garden may be able to assist the Park with growing material for outplanting.

Proposed New Trails from Visitor Center to Honokōhau Bay and Existing Trails to Kaloko Pond

Description of features and vegetation. - The Park GMP proposed a system of trails centered on the Visitor Center that will access the shore and many of the Park's important features (National Park Service 1994b) (Fig. 7). These trails will be walking trails for visitors, and in some cases, will also be used by Park Maintenance personnel on All Terrain Vehicles (ATV). Except for the coastal and access trails to *Honokōhau* beach, trails in the *Honokōhau* section of the Park are still being planned and have not yet been fully developed. In the *Kaloko* section of the Park, two primary trails have been cleared and are being maintained to provide access for visitors and Park staff; these are the *Hu`ehu`e* Ranch Road that runs *mauka-makai* near the *Kaloko/Honokōhau ahupua`a* boundary and a trail circling the east and north sides of *Kaloko* Pond from the jeep road leading to the fishpond from the highway. The use of the existing access road to *Kaloko* Pond from the Queen *Ka`ahumanu* Highway will eventually be phased out (National Park Service 1994b). The coastal trail is discussed in a later section.

The proposed Visitor Center will be the starting point for several planned trails: a boardwalk on the Park`s most recent lava flow that will provide access to a *hōlua* and a view of *`Aimakapā* Pond; an access trail north across unvegetated *`a`ā* to connect with the *Māmalahoa* Trail (discussed elsewhere) and then the old *Hu`ehu`e* Ranch Road; and a new trail that will pass south of the *`a`ā* flow and *`Aimakapā* Pond to connect with the coastal trail along *Honokōhau* Bay. The new trail from the Visitor Center through *Honokōhau* will begin in the formerly bulldozed area on *`a`ā* that is currently very sparsely vegetated with fountain grass. From the *`a`ā* flow and a disturbed area now used for equipment storage, the proposed trail passes into a densely vegetated alien shrubland on old *pāhoehoe* substrate. The dominant alien shrubs here are *ēkoa, klu* (*Acacia farnesiana*), and Christmas berry (*Schinus terebinthifolius*). There are also scattered low *kiawe* trees, and the ground cover is primarily fountain grass. Common native shrubs that are found throughout this alien shrubland are *`ilima* and *`uhaloa*. Several native shrubs rare or uncommon in the Park are visible from the flagged trail route, but will not be negatively impacted by the trail; these are *ko`oko`olau*, *pua pilo*, *`a`ali`i*, and *`ilie`e*.

To the west, the proposed *Honokōhau* ATV trail enters closed *kiawe* forest with a relatively open understory of *ēkoa*, Christmas berry, *Achyranthes aspera*, coral berry (*Rivina humilis*), scattered fountain grass, and patches of Guinea grass (*Panicum maximum*). Archaeological or historic period features that the *Honokōhau* Trail will pass include two corrals with massive walls, possibly used as goat pens; a large pavement in a flat area between clusters of features; one or two house platforms; and features that are either burials or religious structures (Emory and Soehren 1971). Two structures identified as tombs by Emory and Soehren were considered to be significant features because of the use of large slabs as facing, an unusual construction technique found elsewhere in the *Honokōhau* area. *Kiawe* trees and alien shrubs are currently growing on or near some of the walls and platforms, and clumps of grass and shrubs obscure the outlines of many of the features. Ivy gourd, a fast-growing alien vine that has recently invaded the Park, is a potential threat to archaeological and historical features in this area; the vine typically forms a large, swollen root that is difficult to extract. Within the *kiawe* forest near the southeastern part of *`Aimakapā* Pond, the proposed *Honokōhau* Trail turns south to join an old jeep road that is currently used as an access trail to the boundary with the *Honokōhau* Harbor and has a western fork that ends at the beach near *`Ai`ōpio*. Eventually, another foot trail may be routed from the proposed *Honokōhau* ATV trail through the coastal *kiawe* forest between *`Aimakapā* and *`Ai`ōpio*; this trail will be out of sight of the edge of the fishpond to avoid disturbing rare waterbirds (Laura Schuster, pers. comm. 1997).

The *Hu`ehu`e* Ranch Road passes for much of its length through very sparsely vegetated *`a`ā* and broken *pāhoehoe*. Except for patches of older *pāhoehoe* that have a dense cover of fountain grass, the alien vegetation along the road consists of very scattered fountain grass, low Christmas berry shrubs, and a few scaly swordferns (*Nephrolepis multiflora*). In a few places, alien beggarweed shrubs (*Desmodium tortuosum*) have invaded the verge of the old road. Native shrubs, such as *`uhaloa, `ilima, pua pilo,* and *alahe`e* also grow on the nearly bare lava substrate. Near the junction of the *mauka/makai* road with the coastal trail, shrubby vegetation is denser, and the road passes through a patch of *naupaka kahakai*, Christmas berry, and sourbush (*Pluchea symphytifolia*). A number of burials and possible house sites have been identified along the coastal foot path and the route of the *Hu`ehu`e* Ranch Road parallel to the coast (Emory and Soehren 1971).

The *Kaloko* Pond Trail starts at the cleared agricultural features near the existing jeep road from the highway to the Pond, and for most of its length, the trail passes through a mixed shrub/grass vegetation of *ēkoa* and *klu* with a ground cover of dense fountain grass. Native shrubs such as *pua pilo* and *alahe`e* were avoided during trail clearing. Near the northern part of *Kaloko* Pond, the trail passes through the edge of *kiawe* forest with an understory of alien shrubs and patchy grass cover. Near the northern Park boundary, the trail emerges from the edge of the *kiawe* forest into more open vegetation of fountain grass and alien shrubs.

Current or past vegetation management at site. - The proposed *Honokōhau* walking/ATV trail route has been selected, but trail clearing and construction has not yet begun (note: trail clearing had begun by 1999) . There is no current vegetation management activity in the immediate area, although the proposed *Honokōhau* Trail passes near an area on the southeastern edge of *`Aimakapā* Pond, where *kiawe* was cut and removed several years ago.

The old *Hu`ehu`e* Ranch Road was cleared and reconstructed to accommodate ATV use in 1995. The initial clearing and reconstruction of this trail involved the herbicidal treatment of a group of alien plant species and the manual removal of cut material, as well as resetting bulldozed rocks to the width of an ATV. This special project was carried out on 1,136 m (3,750 ft) of trail, and the primary targets of treatment with the herbicide Roundup were Christmas berry, fountain grass, *kiawe, ēkoa*, and *klu* (KAHO files). In 1995, it was estimated that 8-10 herbicide applications would be necessary to clear the trail of alien vegetation, but future vegetation management to prevent alien plant encroachment will likely require less effort.

The ATV-accessible trail that partly circles *Kaloko* Pond extends from the current *Kaloko* access road to the beach trail at the Park's northern boundary. The *Kaloko* Pond circle trail follows an old bulldozed road for most of its length, but the part of the route through *ēkoa* shrubland was almost entirely obscured by dense fountain grass and alien shrubs before clearing was initiated. The alien vegetation along the *Kaloko* Pond trail was cleared manually, and the parts of the trail through shrub/grassland are maintained by weed-whacking encroaching or resprouting vegetation, primarily fountain grass. Only manual clearing of alien plants is done here because there is concern on the part of Park staff over the use of herbicides at this site adjacent to *Kaloko* Pond.

Vegetation management needed to achieve desired condition. - Clearing alien vegetation from the proposed *Honokōhau* ATV and walking trail will require an initial effort at least as great as the *Kaloko* Pond circle trail. Additional effort will be required to construct a level surface for the trail in the first section within shrub/grass vegetation, as the substrate is uneven and does not follow a previously bulldozed route. Within the *kiawe* forest portion of the *Honokōhau* Trail south of *`Aimakapā* Pond, there are a number of historic and archaeological features that will be visible from the trail. Future interpretation of these sites will be enhanced if grass patches and alien shrubs are removed to allow a clear view from the trail to the most important features. In some cases, *kiawe* and other alien woody shrubs are growing on or near walls and platforms of historic and archaeological features and may be damaging structures. Tall *kiawe* trees form a dense cover

for more than half of the proposed *Honokōhau* ATV trail; these large trees are serving to partially suppress other alien ground cover and should be left in place until replacement native or Polynesian trees are available. If possible, it would be desirable to clear alien grasses from a corridor along the *Honokōhau* ATV and walking trail to reduce hazard fuels and provide a safety zone for visitors in case of wildfire (Jack Minassian, pers. comm. 1998).

The *Hu`ehu`e* Ranch Road and the *Kaloko* Pond circle trail are now clear of vegetation and are providing access to the northern and central sections of the Park. Both trails will continue to require periodic maintenance to prevent reinvasion of alien plants. Grass removal from a corridor along the *Kaloko* Pond circle trail would reduce hazardous fuels here and make the trail safer for visitors.

Recommendations:

- Clear and construct the *Honokōhau* ATV/walking trail from the site of the proposed Visitor Center to other trails that access the shore at *Honokōhau* Bay.
- Remove *kiawe* and other alien shrubs that are damaging historical and archaeological features visible from the trail.
- Clear alien shrubs and patches of alien fountain grass and Guinea grass from areas between the *Honokōhau* ATV trail and features important for interpretation. Removal of Guinea grass should be part of an overall scheme to eradicate the species from the Park.
- Leave tall *kiawe* trees in place along the *Honokōhau* ATV trail to provide shade and suppress alien ground cover until native and Polynesian trees and shrubs are available as replacements.
- Remove the invasive ivy gourd from this area; this recent invader should be eradicated from the Park, if possible.
- Continue to treat alien vegetation on the route of the old *Hu`ehu`e* Ranch Road as needed to maintain a clear trail. Periodically monitor this area for the noxious puncture vine (*Tribulus terrestris*) that formerly occurred here and manually remove any individuals found.
- Continue to keep the *Kaloko* Pond circle trail open by cutting alien shrubs and manually cutting resprouting and reinvading fountain grass. Explore the possibility of using acceptable herbicides (such as Rodeo) as cut-stump treatments on shrubs to reduce the workload on this trail.

Restoration of native or Polynesian plants. - The proposed *Honokōhau* ATV trail will pass examples of several native woody plant species in the shrub/grassland vegetation between the Visitor Center and the coastal *kiawe* forest. Those species unnaturally rare in the Park, such as *ko`oko`olau* and *`a`ali`i* will profit from having their numbers augmented with outplantings of young plants propagated from seed sources within the Park. In a recent outplanting of seven *ko`oko`olau* propagated by the Amy Greenwell Ethnobotanical Garden from seeds collected in the Park, all plants re-introduced to the Park (in a small area east of *`Aimakapā* Pond at the base of the *`a`ā* flow) have survived for more than six months and have grown in height. The simple sowing or planting of native plant seeds (collected in the Park) should also be investigated as a restoration technique.

The upper part of the *Hu`ehu`e* Road passes through nearly barren *`a`ā* that is naturally sparse in vegetation. In a recent questionnaire sent to Park advisors, more than half suggested *noni* as a possible shade plant along the route of the road now developed as an ATV/walking trail. Other tree species suggested as plantings along the old *Hu`ehu`e* Road are probably most appropriate to the coastal part of the trail (discussed in the beach and coastal strip section); questionnaire respondents recommended *loulu*, *hau*, *milo*, coconut, and *lama*.

There is no pressing need for additional shade trees along the *Kaloko* Pond circle trail, as *kiawe* and tall alien shrubs are scattered along the route. However, this is a visible and accessible site to use for outplantings of *naio*, *`a`ali`i*, and *pua pilo*, native woody species that already grow in this section of the Park

and would benefit from augmentation of low population numbers. When *kiawe* trees die or are cut, they should be replaced with native or Polynesian tree species.

Recommendations:

- Outplant additional individuals of native shrubs already in the open shrub/grassland portion of the proposed *Honokōhau* ATV trail; examples of species to plant are *ko`oko`olau, `a`ali`i, `ili`e`e,* and *pua pilo.* Such outplantings will be an initial step in the restoration of the cultural landscape of the site. Investigate native plant seed sowing or planting as a potential restoration technique.
- At a point on the proposed *Honokōhau* ATV trail with a good view of the *hōlua* on the *`a`ā* flow to the north, remove alien grasses and plant a patch of *pili* grass (see section on *hōlua* below).
- Evaluate the need for shade along the upper part of the old *Hu`ehu`e* Ranch Road now developed as an ATV/walking trail. At areas where shade is desired, plant several *noni* on the side of the trail where no historic or archaeological features will be affected.
- As part of the restoration of native and Polynesian plant species in the coastal strip, outplant coconut palms, *hau*, and *milo* trees along the coastal portion of the old *Hu`ehu`e* Ranch Road. Consider the introduction of *loulu* palms and *lama* trees to this coastal area.
- Clear several areas of fountain grass and alien shrubs along the *Kaloko* Pond circle trail and plant shrubs native to the area; examples are *`a`ali`i, pua pilo*, and *naio.*

Hōlua and Other Sites on `A`ā Flow East of `Aimakapā

Description of features and vegetation. - The *`a`ā* flow east of *`Aimakapā* Pond supports a number of archaeological and cultural features; some of these may be visible from proposed trails and a boardwalk from the planned Visitor Center on disturbed *`a`ā* near the Queen *Ka`ahumanu* Highway (National Park Service 1994b). The single *hōlua* within Kaloko-Honokōhau NHP is found near the western edge of the *`a`ā* flow, overlooking *`Aimakapā* Pond; this is one of the most significant archaeological/cultural features within the Park. One of only eight surviving *hōlua* in the *Kona* area (Greene 1993), it is unusually wide, perhaps to accommodate two contestants at once (National Park Service 1994b). *Hōlua* (*kahua hōlua*) or sledding tracks were constructed for the chiefly sport of competitive sledding. Apparently, when these rocky sled tracks were in use, they were covered by beaten earth and grass to make a smooth, fast surface (Hiroa 1964). The *Honokōhau hōlua* is 4.5 m (15 ft) wide at the top and 7.6 m (25 ft) wide at the bottom, and is raised 1.2-1.5 m (4-5 ft) above the flow surface. The *hōlua* has a level runway about 30.3 m (100 ft) long, after which there is a hump and a downhill stretch ending at the bottom of the flow. The lower part of the *hōlua* has been disturbed by the removal of rocks, perhaps for adjacent walled features (Emory and Soehren 1971). The *hōlua* has been stabilized (Greene 1993). Adjacent to the *hōlua* is an early 20th century graveyard, including cist burials, a concrete tomb, and graves from the 1920s with concrete curbs (Emory and Soehren 1971).

In a survey of the coastal sections of *Kaloko, Honokōhau*, and *Kealakehe* in 1961, Emory and Soehren ranked these archaeological and cultural features among the most important sites to be preserved in *Honokōhau.* Other features noted near the western end of the *`a`ā* flow were an old trail crossing the flow and a large clearing of unknown purpose. A foot trail of more recent origin follows the southern edge of the *`a`ā* flow and ends at the edge of the disturbed site currently used for maintenance equipment storage; this trail is not one of those to be developed for visitor use (National Park Service 1994b).

The *`a`ā* flow that supports the *hōlua* is the youngest substrate in the Park; this flow in the central part of the Park originated on *Hualālai*'s northwest rift and has been dated at 1,000-3,000 years bp (Moore *et al.* 1987). Vegetation on this flow is extremely sparse. Canfield (1990)described this area as barren inland *`a`ā* with a low cover of the lichen *Stereocaulon vulcani* in cracks. A subsequent survey of Park vegetation found virtually no plant cover on this *`a`ā* flow in the first 400 m (1,320 ft) from the Highway, other than lichen and very scattered *`uhaloa.* The 80 m (264 ft) on the edge of the *`a`ā* near *`Aimakapā* Pond was vegetated with scattered fountain grass, *ēkoa*, lantana (*Lantana camara*); at the very edge of the flow a few native plants

were observed, including large individuals of the shrub *pua pilo*, scattered *`uhaloa*, and patches of the vine *koali`awa* (Pratt and Abbott 1996b).

Current or past vegetation management at site. - There is no current vegetation management of vegetation at the sites of the *hōlua*, the adjacent cemetery, or other features on the *`a`ā* flow east of *`Aimakapā* Pond. One recent vegetation management project was undertaken to the west of the *hōlua,* at the base of the *`a`ā* flow and on *pāhoehoe* substrates east and south of the fishpond; in this project *kiawe* trees were cut and removed (See *`Aimakapā* Pond section).

Vegetation management needed to achieve desired condition. - As the *hōlua* itself is currently bare of vegetation and only scattered fountain grass is found nearby, no active vegetation management is required at this site. The adjacent graveyard and nearby old trail are similarly bare of vegetation. Periodic monitoring to confirm that fountain grass or other alien species are not intensifying near the important features and that no new alien plants have invaded the area may be the only management required at this site. One recent alien plant invader of the Park, ivy gourd, has been observed within *kiawe* forest and in cleared areas near the edge of the *`a`ā*. While this species is not likely to invade the nearly barren *`a`ā*, it is a example of an alien plant that should be controlled Park-wide, if possible.

When the ATV trail south of the *`a`ā* flow is established, the view of the *hōlua* from the trail should be maintained by removing any alien shrubs or large clumps of fountain grass on the edge of the *`a`ā* flow that obscure this prominent feature from appropriate vantage spots on the trail.

Recommendations:

- Monitor alien plant presence on the nearly bare *`a`ā* near the *hōlua* and the adjacent cluster of graves.
- Remove alien shrubs on the edge of the *`a`ā* flow that interfere with a view of the *hōlua* from the proposed ATV/walking trail to the south (see section on proposed trails).

Restoration of native or Polynesian plants. - There is no justification for adding any native or Polynesian plants to the *`a`ā* flow near the *hōlua* and other important features. The natural condition of the site is barren lava, and good visibility of the *hōlua* from nearby proposed trails is desirable. As some writers have suggested that *pili* grass was used to smooth the surface of *hōlua* during sledding, it is desirable to provide an example of this indigenous or Polynesian grass as an aid to interpretation at a site near the proposed trail on *pāhoehoe* substrate to the south of the *hōlua. Pili* is extant in the northern part of Park not far from the *Māmalahoa* Trail, so the Park has a seed source for a small-scale demonstration planting of *pili.* The southern edge of the *`a`ā* to the east of the *hōlua* formerly supported individuals of the native shrub *ko`oko`olau*, and this is a potential re-introduction site for this rare plant. This edge of the *`a`ā* near the disturbed site currently used for equipment storage is out of sight of the *hōlua,* and the adjacent modern trail is not one of those to be maintained for visitor access (National Park Service 1994b).

Recommendations:

- No plants are recommended for restoration near the *hōlua* or adjacent cluster of graves.
- Plant examples of *pili* grass in an area to the south of the *`a`ā* flow near a proposed ATV trail (see section on proposed trails).
- Restore *ko`oko`olau* to a site on the southern edge of the *`a`ā* flow where it was growing within the last five years; this site is not in the immediate vicinity of the *hōlua* or other archaeological features.

Māmalahoa Trail

Description of features and vegetation. - The *Māmalahoa* Trail is one of the many significant features of Kaloko-Honokōhau NHP (Greene 1993). The part of the trail extant in the Park runs for approximately

1,515 m (5,000 ft) from the northern boundary to a point on the *`a`ā* lava flow, where the trail was destroyed by construction of the Queen *Ka`ahumanu* Highway (Fig. 7). This is a "type C" trail, built in a straight line with curbstones and wide enough for 1-2 horses; such trails were constructed between 1841 and 1918 and bypassed coastal settlements (Apple 1965). The trail within the Park was cleared of vegetation in 1989-90 during a restoration project that exposed the route of the trail and restored its former appearance by rebuilding curbing with stones on site (Johnson and Somers 1991). Additionally, a bulldozed section of trail south of the current *Kaloko* access road was reconstructed for a length of approximately 85 m (280 ft). Today the restored and reconstructed trail is a conspicuous feature of the *Kaloko* section of the Park, and it provides a functional example of an historic trail that once stretched for many miles in Kona and Kohala Districts.

The current vegetative cover of the Park adjacent to the restored *Māmalahoa* Trail is dominated by fountain grass and *ēkoa,* but other alien shrubs and small trees are also present, most notably *kiawe* and *klu*, and, to a lesser extent *`opiuma* (*Pithecellobium dulce*) and Christmas berry (Pratt and Abbott 1996b). Several native shrub species are also conspicuous along the route of the *Māmalahoa* Trail. *`Ilima* and *`uhaloa* are common on old *pāhoehoe* substrate throughout the adjacent shrubland, while *pua pilo* shrubs and *naio* trees are seen at a few sites along the trail. The northeastern corner of the Park through which the *Māmalahoa* Trail passes also supports a few patches of *pili* grass, although these are not visible from the trail.

Current or past vegetation management at site. - The part of the trail that was obscured by plant cover was cleared of vegetation in 1989-90 prior to and during the rehabilitation and restoration of the historic trail. Photographs taken during the restoration project document the vegetation along the trail before and after clearing (Johnson and Somers 1991); in many places the trail was invisible beneath fountain grass and alien shrubs. After vegetation was cleared from the bed of the trail and a few feet on either side of the curbing, the straight line of the trail was obvious. In most of the photographs, the rocks of the original curbing were present although in disarray. Roundup was used to kill the bases and stumps of plants after mechanical removal of the cut upper portions. The initial vegetation clearing and treating, combined with trail restoration, required approximately 90 worker days (Johnson and Somers 1991). In 1990-1993, annual management of alien vegetation along the restored trail required 2 people for 7 days (14 worker days); by 1994 only 7 worker days were needed to treat both the *Māmalahoa* Trail and the agricultural planters near *Kaloko* Pond (KAHO files). Alien plants targeted for herbicide treatment were *kiawe, ēkoa, klu*, Christmas berry and fountain grass, but a number of herbaceous alien species and the common native shrub *`uhaloa* were probably also treated to maintain clear conditions on the bed of the trail.

Vegetation management needed to achieve desired condition. - The initial clearing efforts of the rehabilitation project were thorough, and Park workers have been able to continue maintenance of the cleared trail by 5-8 retreatments per year (KAHO files). The management of alien plants by spraying with Roundup should be continued at roughly two month intervals or at a longer interval if continued periodic treatment reduces the level of alien plant re-invasion. Park staff members carrying out alien plant control will be the best judges of the appropriate retreatment schedule. The targets of the current effort to keep the *Māmalahoa* Trail clear are reinvading alien plants; this will be a long-term project, as alien plants will likely predominate in the area for the foreseeable future.

Recommendations:

- Continue to maintain clear conditions along the *Māmalahoa* Trail by periodic retreatment of alien plants with Roundup.
- Experimentation should be undertaken to determine whether herbicides developed for use on woody species (such as Garlon 3A or Garlon 4) will be more effective on alien shrubs at this and other control sites; the goals of such small-scale tests are reduction of the number of retreatments, increase in interval between treatments, and the reduction in the amount of herbicide used in the Park.

Restoration of native or Polynesian plants. - As the portion of the Park traversed by the *Māmalahoa* Trail is somewhat removed from the ocean breeze and may be very hot at midday, shade from existing trees is welcome to hikers on the trail. The largest trees in this area are *kiawe*, which are not part of the overall cultural scene desired for the park, but may be less inappropriate along a trail built between 1840 and 1855. *Kiawe* was an early introduction to Hawai`i, arriving in Honolulu in 1828 (Wagner *et al.* 1990). The date of its introduction to the *Kona* area is not known. Elsewhere in the Park, *kiawe* has been identified as a target for removal (National Park Service 1994b; National Park Service 1996b). Any large *kiawe* trees that are removed to protect the trail or other archaeological resources adjacent to the trail should be replaced with native or Polynesian species appropriate to the area (*e.g. naio* and *noni*).

More than half of the respondents to a recent questionnaire on plant restoration to the Park did not think that it was appropriate to outplant trees along the *Māmalahoa* Trail. Because it is questionable whether trees were prominent in this area during the early historic period, any plants considered necessary for shade along the trail should be native and Polynesian species already in the area. This limits the Park to *naio* and large *noni* that are currently scattered along the northern part of the trail; the largest individuals of these species adjacent to the trail should be found and those at appropriate intervals along the trail should be freed of encroaching alien plants and encouraged to grow.

Recommendations:

- Allow large *kiawe* to stay in place near the *Māmalahoa* Trail as shade trees unless they are harming archaeological features.
- At intervals of several hundred feet, replace *kiawe* or other large alien woody species removed from the trail corridor with plantings of *noni* or *naio*.
- Encourage existing *naio* and *noni* along the trail by clearing alien vegetation around them and providing a space beneath the larger individuals.

Potential View Screens at Park Boundaries with Ka`ahumanu Highway and Honokōhau Harbor

Description of features and vegetation. - The eastern boundary of the Park is a strip of land beside the busy Queen *Ka`ahumanu* Highway. Just upslope of the highway is a rocky slope supporting large commercial buildings of the *Kaloko* Light Industrial Area (Fig. 7). The existing vegetation of this part of the park is dominated by fountain grass and *ēkoa* with other alien shrub species and scattered emergent *kiawe* trees. A few alien plants have been outplanted along the highway adjacent to the Park boundary. Species selected for this dry area by the Department of Transportation are hardy alien trees and shrubs with showy flowers, including bougainvillea (*Bougainvillea* spp.), Indian coral tree (*Erythrina variegata*), and royal poinciana (*Delonix regia*). None of these species are appropriate to the cultural landscape of the Park, but the sparse plantings along the highway are hardly visible from within the Park and are unlikely to spread into the Park itself. It is preferable for visitors to see either native plants or bare lava, rather than alien ornamentals, near the entrance to the Park at the proposed Visitor Center. A screen of vegetation is needed near the eastern Park boundary to mute the noise of the highway and to block the modern developments of road and industrial area, particularly in the northern half of the Park.

The southern extent of the Park is the *ahupua`a* boundary between *Honokōhau* and *Kealakehe*. Approximately 150 m (500 ft) of the southern boundary nearest the Queen *Ka`ahumanu* Highway is a very sparsely vegetated *`a`ā*. Most of the southern boundary passes through a mixed scrub vegetation dominated by *ēkoa* and fountain grass with *klu* and scattered taller *kiawe*. A bulldozed berm of rock and soil just outside the Park boundary has been planted with many bougainvillea shrubs, including cultivars with varied inflorescence colors. West or *makai* of the trail that crosses the berm into the *Honokōhau* Harbor complex, *kiawe* trees grow more densely and are the dominant tree in a strip of coastal forest (Canfield 1990). A screen of vegetation is most desirable in the central section of the southern boundary, where the low scrub vegetation does not obscure the buildings and stored boats of the *Honokōhau* Harbor.

Current or past vegetation management at site. - No vegetation management is currently underway at the eastern boundary of the Park along the Highway, although the northern and southern boundaries have been recently delineated with posts and wire, and alien plants have been cleared from a narrow swath along the open fence line.

Vegetation management needed to achieve desired condition. - Ideally, a screen of vegetation along the Park's eastern boundary would block the view of traffic on the Queen *Ka`ahumanu* Highway from within the Park and reduce the visual impact of the up slope development at the *Kaloko* Light Industrial Area. The potential mature height and size of plants selected for screening will influence the view experienced by visitors at likely viewing spots throughout the Park; the primary viewing spots are near the coasts at *Kaloko* Pond, *`Aimakapā* Pond and beach, and *`Ai`ōpio.* It is unlikely that the *Kaloko* Industrial Area can be entirely screened from view, but views from coastal sites may be softened by the addition of relatively dense plantings near the boundary with the Highway right of way. It may be most effective to leave the alien shrubs in place on the actual boundary to help screen the view and noise from the highway and set the plantings well in from the boundary.

The most important vegetation management activity near both the eastern and southern Park boundaries is the preparation of the site for future outplantings of native and Polynesian plant species here. It is likely that some form of drip irrigation system will be required to encourage tree species to grow quickly to their maximum height in these harsh and dry site.

Recommendations:

- Prepare the area near the eastern boundary of the Park with the Queen *Ka`ahumanu* Highway to receive tree and shrub outplantings when a large number of appropriate species are propagated and available to be planted.
- Work with the State Department of Transportation to prevent future ornamental outplantings of alien trees and shrubs along the Highway fronting the Park's eastern boundary.
- Prepare the middle section of the Park's southern boundary between the *`a`ā* flow and the coastal *kiawe* forest for future outplantings.

Restoration of native or Polynesian plants. - While a vegetative screen along the Park boundaries is to some degree unnatural, it is nonetheless desirable to use native or Polynesian plants for this purpose. In a questionnaire sent to advisors of the Park, more than half of the respondents suggested the indigenous trees *hau* and *hala* as appropriate species for a vegetative screen. Other Polynesian species proposed for this use are *kou*, *ulu* (*Artocarpus altilis*), *kukui*, *noni*, and *niu* or coconut palm. Native trees and shrubs suggested by at least one advisor include *alahe`e* and *loulu* palm; while both of these are likely appropriate to the area, they are probably too slow-growing to be used for the bulk of the screen. The hardiest and fastest-growing native and Polynesian species that are likely to grow with dense foliage should be used for most of the vegetative screen along the eastern boundary with the Queen *Ka`ahumanu* Highway, and other species may be filled in later, as they became available. Coconut palms are a good choice for planting along the southern boundary, as tall straight trunks will help break up the distant view of boat masts and tall, multi-storied boat storage structures. Rows of coconut palms appear to be doing well with irrigation along the *Honokōhau* Harbor access road. Discussion at the *Kona* Parks scoping session in 1996 emphasized the point that a regular, straight-line planting is less desirable than an irregular planting of different species of varying heights and forms.

Recommendations:

- Obtain seeds and propagules of appropriate native and Polynesian tree and shrub species either from the Park or from sources near the Park. Examples of species to start with are *hau*, *hala, kou*, coconut palm, and *noni.*

- As large numbers of individual plants will be needed for outplanting a vegetative screen along portions of both the eastern and southern boundaries, the Park may need to develop a temporary nursery on site or make arrangements for large-scale plant propagation with other organizations, such as Amy Greenwell Ethnobotanical Gardens.
- It may be possible to purchase some species, such as coconut trees, from commercial plant nurseries in the *Kona* area. If commercial sources are used, care must be taken to obtain the appropriate "Hawaiian" cultivars of coconut, rather than the "Samoan" type.

Kaloko Fishpond and Nearby Agricultural Features

Description of features and vegetation. - *Kaloko* Fishpond is the most prominent feature within the *Kaloko* section of the National Historical Park; the area around the pond is considered to be of the highest cultural significance and has been designated as a zone in which both historical and natural values are to be preserved (National Park Service 1994b). Approximately 4.5 ha (11 a) in size, *Kaloko* is a *loko kuapā* type of pond, modified from an existing bay by a stone seawall. The seawall of *Kaloko* Pond is the most massive known from ancient fishponds in the Hawaiian Islands (Apple and Kikuchi 1975). Several interior walls delimiting sections within the main pond are also evident at *Kaloko*; most readily seen are a secondary interior fishpond on the north side of the pond and walls across the narrow southeastern arm (Fig. 8). The seawall has been damaged by human activities and high waves and has been rebuilt several times (National Park Service 1994b). *Kaloko* Pond was dredged in 1973, and was estimated to have lost half its original integrity as a fishpond by Apple and Kikuchi (1975). However, from an archaeological perspective, *Kaloko* Pond is considered one of the best remaining island examples of a large Hawaiian fishpond in relatively good condition (Greene 1993). Although the date of aquacultural development at *Kaloko* is not known with certainty, the fishpond is thought to have been in use by the mid-1600s (Cordy *et al.* 1991).

The area surrounding *Kaloko* Pond is rich in archaeological sites. During field work prior to 1961, Emory and Soehren (1971) noted burials, enclosures, house platforms, petroglyphs, and small walled enclosures of uncertain function in the coastal section of *Kaloko*. During the 1970s, archaeological work revealed many more sites, both adjacent to *Kaloko* Pond and in the upslope area within the current Park boundaries; nearly 100 archaeological sites, including *mauka-makai* trails east of the pond, were mapped in *Kaloko* by Cordy *et al.*(1991). Apart from the *Kaloko* Fishpond itself, the archaeological sites that are most visible today are those near the coast and those that have received management attention in the recent past. Most notable are the rock walls and remains of structures near the southeastern arm of the pond and the large complex of oval walled enclosures, now recognized as agricultural features, just southeast of the pond and adjacent to the current access road from the highway. This agricultural complex of more than 60 enclosures was investigated by Renger and later by Cordy and Hitchcock, who interpreted the features as planters for crops with the stone walls functioning to reduce water loss from wind. The features that they excavated contained soil and had no artifacts from the historic period, indicating they were prehistoric structures rather than constructions from the later ranching period (Cordy *et al.* 1991).

Vegetation around *Kaloko* Pond is dominated by alien plants. The margins of the pond are today covered by a low, saltwater-tolerant vegetation in which pickleweed (*Batis maritima*) is dominant. Several native plants grow mixed with the pickleweed, including *`ākulikuli* and *`ōhelo kai* (*Lycium sandwicense*). Pickleweed, a creeping succulent shrub accidentally introduced from tropical America in the mid 1800s (Whistler 1992), has expanded into the area that was formerly covered by American or red mangrove trees (*Rhizophora mangle*) (National Park Service 1996b). A major management project to remove mangrove was undertaken in the early 1990s, and the Park's goal is to eradicate this destructive species from *Kaloko* Pond and all other sites within the Park (National Park Service 1994b). Apart from the replacement of mangrove by pickleweed at the edge of the pond, the vegetation immediately surrounding *Kaloko* Pond remains as it was mapped by Canfield (1990), with a closed *kiawe* forest on the eastern margin and a more open mixed vegetation of *kiawe*, other alien shrubs, and fountain grass on the northern side of the pond. The southern

edge of the pond visible from the access road has open vegetation of scattered *kiawe* trees, mixed native and alien shrubs, and fountain grass. A narrow arm of shallow water on the southeastern margin of the pond supports the largest patch of native *makaloa* sedge (*Cyperus laevigatus*) on *Kaloko* Pond.

A flat, sandy area now used as a parking area at the seaward terminus of the access road to *Kaloko* Pond supports a grove of coconut mixed with *milo* and other alien, Polynesian, and native tree species. This site or one nearby is planned as a cultural development, a live-in Hawaiian cultural center (National Park Service 1994b).

The area surrounding the agricultural features southeast of *Kaloko* Pond adjacent to the current access road was vegetated with a mixed alien shrub and fountain grass vegetation before management efforts cleared the area and exposed the features. The *pāhoehoe* substrates east of *Kaloko* Pond are covered with a dense vegetation of fountain grass and alien shrubs, particularly *ēkoa* and *klu* (Pratt and Abbott 1996b). The more recent *`a`ā* substrate southeast of the pond on which the agricultural enclosures stand is less densely vegetated with the same alien species found on the adjacent *pāhoehoe*, and the alien shrubs Christmas berry and sourbush are conspicuous here. The area near the planters also supports native shrubs of *pua pilo*, *`ilima*, and *naio*.

Current or past vegetation management at site. - In the early 1990s, the Park undertook a major vegetation management project to remove American mangrove (National Park Service 1996b) that had infested *Kaloko* Pond and surrounding wetland for decades. Morin (1994) noted that mangroves invaded *Kaloko* in the 1960s, but Cordy *et al.*(1991) reported that the pond was clear of mangrove during archaeological work in 1971. Mangrove is recognized as one of the most detrimental alien plants to the integrity of Hawaiian fishponds (Apple and Kikuchi 1975), and the tree also reduces wetland habitat available to native water birds (Morin 1994). A team of contract workers, under the direction of Park and University of Hawai`i Cooperative Park Service Unit (CPSU) personnel, manually cut and removed mangrove from *Kaloko* Pond (as well as from a section of *`Aimakapā* Pond), starting in 1991. This effort was highly successful in eliminating mangrove, but pickleweed has moved into some of the area formerly occupied by mangrove (National Park Service 1996b). Pickleweed control methods are currently being investigated on the margin of *Kaloko* Pond.

Manual removal of pickleweed on the southeastern arm of the pond has allowed the increase of native plants, such as *makaloa* sedge and *`ākulikuli*. Adjacent to the manual control test area, a recent project to kill pickleweed with fire from hand-held torches has also shown great promise. Burning the almost pure stand of pickleweed at low tide kills most of the roots; follow-up spot treatment with a torch is necessary at two week intervals for at least two months to kill persistent plants that resprout, as well as new seedlings. Techniques used in these preliminary pickleweed control projects were based on a nearby research plot testing the effectiveness of several treatments and retreatment regimes (Laura Schuster, pers. comm. 1997). Other methods of pickleweed control, such as shading with black plastic, were found to be impractical, and herbicide use was not an option adjacent to the pond (National Park Service 1996b). *Kiawe* has also been cut and removed from the southern and southeastern edge of *Kaloko* Pond.

The current parking area near the southern edge of *Kaloko* Pond is kept clear of alien vegetation, and the coconut grove receives periodic attention to trim dead leaves and clusters of coconuts. Coconut frond trimming is carried out at *Kaloko* Pond approximately every six months (Anthony Texeira, pers. comm 1997).

Vegetation management at the archaeological features now recognized as prehistoric planters began in 1990 with the removal of alien vegetation from five rock wall enclosures near the junction of the *Kaloko* access road with the beginning of the *Kaloko* ATV trail, in a relatively rocky area southeast of *Kaloko* Pond. This initial effort to remove alien shrubs and grasses that were both damaging the structural integrity and obscuring the planter features took 2 workers 5 days to accomplish and was documented in photographs

before and after the project (Johnson and Somers 1991). Vegetation was cut with a weed eater, chain saw, or hand shears, and herbicide was used to treat regrowth. By 1995, this project had been expanded to the control of alien plants in 23 agricultural plantings. Fountain grass and four alien shrubs (*kiawe, klu, ēkoa*, and Christmas berry) were targeted for removal and treatment of cut stumps or clump bases with a dilute solution (ca. 1%) of the herbicide Rodeo in water (Rizal Fronda and Anthony Teixeira, KAHO files). Retreatment was planned five to eight times a year to maintain clear conditions at the archaeological complex. In 1996, this alien plant control effort was continued in an area estimated as 1.1 ha (2.6 a). Native shrubs such as *pua pilo* and *`ilima* near the planters have been avoided and likely benefit from the removal of fountain grass.

Vegetation management needed to achieve desired condition. - A level of vegetation management at least equivalent to current maintenance of alien vegetation is essential in the vicinity of *Kaloko* to take advantage of previous large-scale alien plant control work. Mangroves must be prevented from re-invading *Kaloko* Pond. Preliminary control of pickleweed should be expanded and tied to augmentation of native wetland and strand plants. Large-scale *kiawe* removal near *Kaloko* Pond should be postponed until the methodology of pickleweed control is established and funds are available to control this and other alien species that will likely invade areas now covered by dense *kiawe*. The successful program of vegetation management ongoing at the agricultural enclosures adjacent to the *Kaloko* access road should be continued. Other archaeological, historical, and cultural sites in the vicinity should be evaluated for their importance and prioritized for future alien plant control.

Recommendations:

- Monitor *Kaloko* Pond and the adjacent shoreline and manually remove any propagules or seedlings to prevent reinfestation of mangrove. This periodic maintenance will be required long-term and is particularly important as long as a population of mangrove persists at ponds in the adjacent land division of *Kohanaiki*.
- Continue to use hand-held torch scorching (and manual methods where most appropriate) to remove pickleweed from the margin of *Kaloko* Pond. Expand the area treated as personnel are available to accomplish both the initial and follow-up treatments. A low level of monitoring to determine pickleweed survival and reinvasion rates should be continued, as this will help refine retreatment intervals. Where appropriate, *makaloa* sedge and *`ākulikuli* should be restored to areas after pickleweed is removed. It is desirable to leave some mud flats bare to provide feeding sites for the endangered black-necked stilt or *ae`o* (*Himantopus mexicanus knudseni*) and other native shore birds. Develop a site management plan for the pickleweed removal project.
- Although *kiawe* has been recognized as a serious pest in Hawai`i for its ability to shade out other species and deplete ground water resources (Smith 1985), it is not currently feasible to remove *kiawe* from large areas of the Park. The current dominance of *kiawe* in the forest surrounding Kaloko Pond requires the development of follow-up alien plant control strategies to prevent areas of *kiawe* removal from being reinvaded by other alien plant species. Small-scale *kiawe* removal, coupled with manual or herbicidal control of alien species that subsequently invade clearings should be tested. The use of native species outplantings to suppress alien plant invasions in kiawe removal areas should also be investigated.
- Continue the periodic removal of fountain grass and alien shrubs from the highly visible archaeological site with agricultural enclosures adjacent to the *Kaloko* Pond access road.
- Expand alien plant control from the existing treated site surrounding the agricultural planters to the archaeological complex near the narrow southeast arm of *Kaloko* Pond and the area adjacent to the current parking area along the southern shore. Clearing of fountain grass and alien shrubs from this area will allow the interpretation of features dating from the early 1800s (Cordy *et al.* 1991), and will favor native woody species already in the area (*pua pilo, naio, milo*), thus contributing to the restoration of a more natural landscape in an area that currently receives a high level of visitation.
- Evaluate other areas near the fishpond for alien plant control, such as well-preserved platforms north of *Kaloko* Pond (Emory and Soehren 1971) and sites on the pond's eastern shore that may

combine archaeological sites with areas supporting stands of native plants, particularly *naio*, that may benefit from alien plant removal.

Restoration of native or Polynesian plants. - Restoration of native wetland plants (*makaloa*) and strand species, such as *`ākulikuli* and *`ōhelo kai,* is desirable in some of the areas where pickleweed is removed. It may be possible to grow *makaloa* from seeds in a nursery setting to provide young plants to restore to pond margins with soil after pickleweed is cleared (Peter van Dyck, pers. comm. 1997). Other native plants appropriate to a natural pond edge wetland may be seeded in from remaining nearby plants or may be augmented with cuttings or young plants grown from seed. Native wetland plants that have been found only rarely at *Kaloko*, particularly *`ahu`awa* (*Mariscus javanicus*) and *`ae`ae* or water hyssop are appropriate species to restore to the edge of *Kaloko*.

The area now used as a parking area adjacent to the shore on the south side of *Kaloko* is an appropriate area to introduce or augment native and Polynesian tree and shrub species, as it already supports a grove of coconuts, *milo*, and a few *kou*. Respondents to a recent questionnaire asking for suggestions on native and Polynesian plants to be planted at developed or disturbed sites near *Kaloko* Pond recommended coconut, *milo, kou, `ilima, naupaka kahakai*; and *pua pilo*, species that are now present at or near the coconut grove and should be augmented by additional individuals. Suggestions for additional species to be used for outplanting are *kī*, *noni*, *hau*, and *loulu*. All but *loulu* are already present within the Park, and propagation materials are available.

If archaeological investigations are carried out to determine the type of crops that were grown within the planter features southeast of *Kaloko* Pond, a demonstration planting of the appropriate Polynesian crop species will be valuable for interpretation of the area. Planters to be used for such a demonstration should be chosen only after archaeological clearance and determination that the project will not damage the archaeological features. While the arid coastal plain near *Kailua* was not the primary zone for crop cultivation, sweet potatoes were typically grown here (Kelly 1983).

Future *kiawe* clearing projects near *Kaloko* Pond should include a component of native and Polynesian tree and shrub restoration. *Naio* and *pua pilo,* native plants already well established in the *kiawe* forest surrounding *Kaloko* Pond, are two species that will benefit from augmentation by outplanting in areas currently covered by *kiawe*.

Recommendations:

- Restore native plants to the shores of *Kaloko* Pond after pickleweed removal: *makaloa, `ākulikuli, `ōhelo kai, `ahuawa,* and *`ae`ae*.
- Augment and introduce native and Polynesian shrub and tree species to the edges of the parking lot on the south side of *Kaloko* Pond. Suggestions for outplantings are *milo, kou, `ilima, naupaka kahakai, pua pilo, kī, noni, hau,* and *loulu*.
- After archaeological investigations are carried out, create a demonstration planting of Hawaiian crops in or near the prehistoric planters of the *Kaloko* agricultural complex.
- Restore and augment numbers of native and Polynesian shrubs and trees to the shores of *Kaloko* Pond after *kiawe* removal is accomplished; two suggestions for augmentation are *naio* and *pua pilo*.

`Aimakapā Fishpond and Surrounding Wetlands

Description of features and vegetation. - Covering approximately 6 ha (15 a), *`Aimakapā* Fishpond is the largest of the fishponds/fishtraps within Kaloko-Honokōhau National Historical Park, and is the most prominent feature of coastal *Honokōhau*. *`Aimakapā* Pond is centrally located on the shore within *Honokōhau* land division; the pond has as its western edge the beach along *Honokōhau* Bay, and the eastern edge of the pond abuts the base of a large *`a`ā* flow representing the youngest substrate in the Park (Fig. 9). *`Ai`ōpio*

Fishtrap at the southern boundary of the Park, *ʻAimakapā*, and the area between the two ponds are together considered an area of high cultural significance (National Park Service 1994b). *ʻAimakapā* is a *loko puʻuone* type of fishpond isolated from the ocean by a barrier beach (Apple and Kikuchi 1975); it is uncertain whether there is an artificially constructed seawall beneath the sand of the beach separating *ʻAimakapā* Pond from *Honokōhau* Bay, but remains of a modern sluice gate or *makahā* may be seen on the north side of the barrier beach (Greene 1993). Several internal compartments delimited by rock walls are conspicuous on the northern and eastern shores of the pond; these internal walls are much overgrown by *milo*, a tree species now considered native but formerly called a Polynesian introduction, and by seashore paspalum or knotgrass (*Paspalum vaginatum*), an alien grass widely naturalized in the tropics (Wagner *et al.* 1990). The area of open water was formerly much greater before adjacent wetlands silted in and became overgrown with vegetation (Morin 1994).

A recent map of the pond and wetland vegetation of *ʻAimakapā* shows *kiawe* forest to the north and south and a broken band of *milo* forest almost encircling the pond (National Park Service 1994b). Marsh vegetation is particularly pronounced on the northwest and southwest margins of the pond. Canfield (1990) recognized more than ten distinct associations of marsh plants on the margin of *ʻAimakapā* Pond. More than half of the recognized associations include the alien knotgrass either in pure stands, mixed with the alien pickleweed, or mixed with native sedges, *ʻaeʻae*, or *milo*; knotgrass-dominated marsh and meadow were noted on all sides of *ʻAimakapā* Fishpond. Marsh or wet meadow vegetation composed mostly of native species mixed with alien knotgrass was noted on the north side of *ʻAimakapā;* dominant native plants were *ʻaeʻae*, *makaloa*, and *kaluhā* or *makai* sedge (*Bolboschoenus maritimus* subsp. *paludosus*). An open vegetation of *milo* shrubs in knotgrass meadow was described for the edge of wetter marshes both north and south of the pond.

The beach on the west side of the pond is heavily used by humans and is sparsely vegetated in places, but the area supports a number of native strand species. *Milo, hau, naupaka kahakai*, and coconut palms are relatively common along the edge of the beach near the pond, and the native strand plants *ʻakiʻaki* (*Sporobolus virginicus*) and *pōhuehue* are found as sparse cover on the sandy beach.

ʻAimakapā Pond is notable as a breeding site for the endangered Hawaiian black-necked stilt and the Hawaiian coot (*Fulica alai*); the pond is one of the two most important sites for these and other waterbirds on the island of Hawaiʻi (Morin in prep. a). Within the pond, the eastern side has supported most of the known nests of these two endangered birds in recent years; but this nest placement is probably an artifact relating to the concentration of human presence on the barrier beach on the west side of the pond (Morin in prep. b). Exposed mud flats and many other areas of the surrounding wetland are important feeding sites for stilts and other waterbirds. *ʻAimakapā* is also an important site for migrant ducks and shorebirds, and the pond supports resident waterbirds like the pied-billed grebe (*Podilymbus podiceps*) and black-crowned night heron (*Nycticorax nycticorax*) (Morin 1996; Pratt 1993). Because of the great importance of *ʻAimakapā* Pond as a natural habitat of endangered waterbirds and a valuable resource for migrant waterfowl, any plans for vegetation management near the pond must take into consideration the potential impact of any activity on these birds. The pond is one of only two subzones in the Park where natural resource values are considered to be as important as the cultural and historical values of the site (National Park Service 1994b).

Current or past vegetation management at site. - Mangroves that had infested marsh and near-shore vegetation north of *ʻAimakapā* Pond were manually removed in the early 1990s, as part of the same project that controlled the larger infestation at *Kaloko* Pond (National Park Service 1996b). *Kiawe* trees were cut and removed from the southeastern margin of *ʻAimakapā* in a narrow band adjacent to the prominent *ʻaʻā* flow and in a larger area of flat *pāhoehoe* south of the pond. In the narrow band near the base of the lava flow, *milo* has responded positively and alien shrub invasion has been light after *kiawe* removal, but in the area where *kiawe* was controlled south of the pond, a dense cover of fountain grass and alien shrubs, particularly the prickly *Achyranthes aspera*, has appeared where tall *kiawe* trees were cut and removed. Only near the

edge of the water on the south side of the pond have *milo* trees increased and native low-growing plants, such as *`ākulikuli* and *pā`ū o Hi`iaka* (*Jacquemontia ovalifolia*), appeared after the removal of *kiawe.*

Vegetation management needed to achieve desired condition. - Because of its combination of important natural resources, great cultural value, and archaeological features, *`Aimakapā* Pond is perhaps the most complex management site within Kaloko-Honokōhau National Historical Park. Any vegetation management plan must take into account the needs of the endangered and other native water birds, as well as the potential impact of management on cultural and archaeological features. As native wetland vegetation types are rare on Hawai`i Island, parts of the *`Aimakapā* Pond complex supporting mostly native plant associations, such as the marsh and wet meadow north of the pond, deserve protection apart from their value as habitat for native waterbirds. Some removal of vegetation, both native and alien, may be necessary to prevent damage to interior fishpond walls and archaeological sites within *`Aimakapā* Pond and adjacent wetlands.

Recommendations:

- Develop a vegetation site management plan specifically for *`Aimakapā* Pond in conjunction with a waterbird management plan.
- Target the invasive alien vine of ivy gourd for eradication in the Park and begin control work in area southeast of the pond, where the vine has recently invaded *kiawe* forest and patches of cleared forest. Systematically search the *kiawe* forests and cleared areas surrounding *`Aimakapā* Pond and treat each ivy gourd vine with the herbicide treatment previously found to be effective: a basal bark application of 4% Garlon 4E in diesel oil (Motooka 1989). Ivy gourd seedlings should be uprooted and removed.
- Monitor the ground cover in areas recently cleared of *kiawe* and document the species that replace the original sparse ground cover. Experiment with manual removal of alien grasses and shrubs in cleared areas that have native plant species nearby.
- Do not clear *kiawe* or *milo* from margins of the pond where a vegetative barrier is required to screen waterbird nesting sites from human activity.
- Continue to monitor sites cleared of mangrove and remove any reinvading seedlings.
- After pickleweed control methods are developed at *Kaloko* Pond, target sites on the edge of *`Aimakapā* for pickleweed removal. Naturally the timing and location of such management actions must take into consideration the breeding periods of endangered waterbirds and the need to minimize disturbance to native waterbirds.
- Establish repeatable monitoring of marsh vegetation within both native and native/alien plant associations to help determine the dynamics of wetland vegetation near *`Aimakapā* Pond.
- Evaluate vegetative cover on fishpond walls and other important archaeological features of *`Aimakapā* Pond, and experiment with vegetation control methods that protect the cultural and archaeological features without compromising essential waterbird habitat.

Restoration of native or Polynesian plants. - As the beach vegetation is relatively sparse, native strand species already present (*naupaka kahakai, pōhuehue, pā`ū o Hi`iaka*) will benefit from augmentation. The beach interface with shrubby vegetation is a likely place to restore species recently lost from the Park, such as *hinahina* (*Heliotropium anomalum*) and the annual grass *Panicum faurei* var. *latius.* The beach north and south of the pond provides potential outplanting sites for species appropriate to the Park's desired cultural landscape, such as *loulu*, *hala*, and *kou*.

In order to enhance the possibility for success of future small-scale alien plant removal projects (particularly *kiawe* control), it is desirable to have a stock of propagated native and Polynesian plants available to restore to areas after alien plant removal. *Milo, hau, naupaka kahakai,* and *pua pilo* are good choices for woody plants to restore to areas cleared of *kiawe* south of *`Aimakapā,* but low-growing strand plants may also have value for restoration at some sites.

Recommendations:

- Restore native coastal plant species missing from Park, but previously documented as present: *hinahina* and the annual grass *Panicum faurei* var. *latius.*
- Augment existing native plant populations along coast with outplanted individuals of *naio, naupaka, kīpūkai* (*Heliotropium curassavicum*), *pōhuehue, pa`u o Hi`iaka*, and *pua pilo.*
- Restore native and Polynesian plant species that were likely found along the coast during the early historic period, but have been lost from the Park or greatly decreased in numbers: *loulu, hala, kou.*

`Ai`ōpio Fishtrap and Pu`uoina Heiau

Description of features and vegetation. - The *`Ai`ōpio* Fishtrap and adjacent *Pu`uoina Heiau* are found on the shore at the extreme southwestern corner of the Park, just north of the Park boundary and the entrance to *Honokōhau* Harbor. Along with *Kaloko* and *`Aimakapā* Ponds, the *`Ai`ōpio* Fishtrap is one of the most significant archaeological and cultural features of Kaloko-Honokōhau NHP. Approximately 0.8 ha (2 a) in size and roughly circular, the fishtrap is composed of a stone seawall attached to a rocky headland and has four stone-walled enclosures near the shore (Greene 1993) (Fig. 10). The structure is called a fishtrap rather than a fishpond because of the presence of the internal enclosures, probably used as holding pens for fish, and because of the absence of a *makahā* or sluice gate (National Park Service 1994b). Apple and Kikuchi (1975) rated the integrity of this royal fishtrap relatively high compared with more than 50 extant fishponds they surveyed. Although Emory and Soehren (1971) recommended the *`Ai`ōpio* Fishtrap for preservation, they devoted very little space to its description, except to comment on its state of disrepair and broken seawall.

By contrast, the *Pu`uoina Heiau* on *Mali`u* Point adjacent to the fishtrap was described in detail by Emory and Soehren, who were impressed with its "magnificent south wall" built of massive water-worn slabs and considered the structure "the finest example of a platform type of *heiau* in Kona" (Emory and Soehren 1971). They measured the *heiau* platform as 15 x 44 m (50 x 145 ft) and found it well preserved despite the removal of stones for nearby modern walls and the presence of adjacent fishermen's houses. To the north of the *heiau* near the shore, a large platform and associated burials were also mapped (Fig. 10). This *heiau* was listed without description or illustration in Stokes' survey of the *heiau* of the island of Hawai`i carried out in the early 1900s (Stokes and Dye 1991). *Pu`uoina Heiau* may have been an important site for directing fishing activities at the adjacent *`Ai`ōpio* Fishtrap and elsewhere in *Honokōhau ahupua`a* (Greene 1993).

The walls of the *`Ai`ōpio* Fishtrap are periodically washed by waves and currently support no terrestrial vegetation. The beach facing the fishtrap supports scattered coconut palms, and the sand substrate is sparsely vegetated with a mixture of herbaceous native and alien plants; *`aki`aki* grass is the most abundant native plant on the beach and Bermuda grass is the most common alien. On the beach nearest *Pu`uoina Heiau*, there are shrubby tree heliotropes (*Tournefortia argentea*) and a few natives, such as *naupaka kahakai, kīpūkai, pōhuehue*, and *pā`ū o Hi`iaka.* Just in back of the beach and beyond walls associated with the *heiau,* there is a clump of *milo* and *kiawe* trees on the Park boundary with *Honokōhau* Harbor lands to the south.

The vegetation surrounding the *heiau* was mapped in 1990 as a patchwork of *kiawe* and fountain grass with a large area near several anchialine pools dominated by pickleweed (Pacific Islands Support Office and KAHO files). Except for *kiawe* trees removed in 1990 (Johnson and Somers 1991), these components of vegetation surrounding the *heiau* persist in 1998. In addition to these vegetation dominants, there are scattered individuals of approximately 12 alien species on and immediately adjacent to the *heiau*, not including species purposely planted. The alien plants most threatening to the *heiau* are the remaining *kiawe, ēkoa*, sourbush, and ivy gourd. The noxious and prickly puncture vine, a recognized pest on beaches and trails, grows in sandy substrate near the *heiau.* Alien ornamental or cultivated plants that appear to have been intentionally planted beside the *heiau* in the recent past include aloe (*Aloe vera*), sisal (*Agave sisalana*),

carrion flower (*Stapelia gigantea*), bowstring hemp (*Sansevieria trifasciata*), wild spider flower (*Cleome gynandra*) and tobacco (*Nicotiana tabacum*).

Vegetation immediately adjacent to the beach to the east or *mauka* of *`Ai`ōpio* has been disturbed by years of human activity and includes remnants of a cultivated garden. A mixture of traditional Polynesian crop plants and useful tree species, food plants introduced to Hawai`i in recent times, alien ornamental species, and a few accidental introductions in pots were noted within the garden area in June 1997 (Pratt 1997). Traditional crop plants within the garden include *maia* (*Musa* sp.), *`uala* or sweet potato (*Ipomoea batatas*), *wauke* (*Broussonetia papyrifera*), *ulu* or breadfruit, and *kī*. Individuals of the Polynesian tree species *kou* and *kukui*, as well as native *milo,* are present as potted plants in the garden; *hala* trees in the vicinity of the garden may also have been planted. Alien food plants in the garden as potted plants or growing in beds are *liliko`i* (*Passiflora edulis*), macadamia nuts (*Macadamia ternifolia*), tomato (*Solanum lycopersicon* var. *cerasiforme*), balsam pear or bitter melon (*Momordica charantia*), and papaya (*Carica papaya*). Alien ornamentals within the garden (some of which have medicinal, fiber, or other uses) are aloe, money plant (*Pleomele marginata*), plumeria (*Plumeria* sp.), crown flower (*Calotropis gigantea*), bowstring hemp, *laua`e* fern (*Phymatosorus grossus*), calabash tree (*Crescentia cujete*), and chandelier plant (*Kalanchoë tubiflora*). Likely accidental introductions to the garden in pots and potting soil are buffelgrass (*Cenchrus ciliaris*), hairy crabgrass or *kupaepua`a* (*Digitaria setigera*), and banyan (*Ficus* sp.); the alien broadleaf plantain or *laukahi* (*Plantago major*) may have been planted as a medicinal herb or have arrived accidentally with other plantings.

Mauka or east of the garden area near *`Ai`ōpio* are scattered *milo* trees and an open grassy area of alien knotgrass with native *`aki`aki* grass and *`ākulikuli*. This area appears to be an intermittent wetland, as it sometimes has standing water. Inland of this grassy area is a dense forest of *kiawe* with an understory of predominantly alien plants (Canfield 1990). The northern stretch of the beach at *`Ai`opiō* is edged by coconut, *milo, naupaka*, Christmas berry and *kiawe* to the point where the access trail from the *Honokōhau* boundary reaches the shoreline after passing through *kiawe* forest (vegetation map in Pacific Islands Support Office and KAHO files). A replica of a canoe house has been recently constructed on the beach just north of *`Ai`ōpio* (National Park Service 1997a), and the immediate vicinity of this structure is currently unvegetated.

Current or past vegetation management at site. - As modern inhabitations were present on the walls of *`Ai`ōpio* Fishtrap until recently, the complete absence of plants may be due to human use of the fishtrap; the absence of vegetation is desirable for preservation of this important archaeological and cultural feature. The adjacent *Pu`uoina Heiau* received vegetation management during the stabilization of the north wall of the *heiau* in 1990, when trees and fountain grass were removed (Johnson and Somers 1991). The project log stated that mostly small *kiawe* trees were removed, but one large *kiawe* and two coconut palms were removed to prevent damage to the northern wall and northeast corner of the *heiau*. Several non-native ornamentals have been planted on and adjacent to the *heiau*, probably by people living in the area; some of these persisted in 1997. The area *mauka* of the fishtrap and beach was developed as a garden by recent inhabitants of the area, and a number of alien plants and Polynesian species remained in place in 1997. The trail that enters the *`Ai`ōpio* area through *kiawe* forest to the east and connects to a trail from the *Honokōhau* Harbor boundary to the south is maintained for visitors and Park staff.

Vegetation management needed to achieve desired condition. - The walls of the *`Ai`ōpio* Fishtrap do not currently require any vegetation management, but periodic monitoring may be needed to ensure that alien mangrove propagules from north of the Park or native *milo* from the surrounding forests do not become established on walls of this important archaeological and cultural site. *Pu`uoina Heiau* will require periodic vegetation management to prevent reinvasion of *kiawe* and alien shrubs damaging to the integrity of this important archaeological feature. Several recent plantings of non-native ornamental plant species should be removed from the *heiau* to enhance the cultural landscape of the site. Two particularly noxious alien species recently found at the *heiau*, puncture vine and ivy gourd, should be eradicated from the area before they spread farther. The anchialine pools adjacent to the *heiau* represent both a cultural and a natural resource;

when an effective treatment for pickleweed is found, this alien species should be targeted for control near *Pu`uoina Heiau.* Plantings at a former garden site *mauka* of the *`Ai`ōpio* beach should be evaluated for appropriateness to the area, and those not appropriate to the cultural landscape should be removed, along with remaining plastic pots.

Recommendations:

- Periodically monitor the walls of the *`Ai`ōpio* Fishtrap to prevent establishment of mangrove, *milo*, or other plant species adapted to brackish water.
- Maintain clear conditions on *Pu`uoina Heiau* by periodically removing invading alien shrubs or other species that may damage the structure of the temple.
- Remove inappropriate plantings of alien ornamental or crop plants on or adjacent to the *heiau:* sisal, carrion flower, wild spider flower, tobacco, and bowstring hemp.
- Control ivy gourd invading rocky sites near *Pu`uoina Heiau* to prevent a more serious infestation that may damage archaeological features, and remove puncture vine from the *heiau* and the beach at *`Ai`ōpio* to prevent establishment and spread of this prickly alien plant. Park beaches and trails are particularly vulnerable to puncture vine.
- Control alien pickleweed surrounding the anchialine pools near *Pu`uoina Heiau* after an effective technique is developed at *Kaloko* Pond.
- Remove inappropriate plantings of alien ornamental and food plants and remaining plastic pots from the garden site just east of the beach at *`Ai`ōpio.* Leave native and Polynesian species that are appropriate to the area, such as *hala, kī, kou*, and *milo.* Some of the plantings of Polynesian species, such as *`uala*, *wauke, maia*, *ulu*, and *kukui* will probably not survive unless cared for and will disappear on their own.

Restoration of native or Polynesian plants. - The area just upslope of the beach at *`Ai`ōpio* has been recently inhabited and partly used as a garden, and some open areas currently vegetated with alien plants may be likely outplanting sites. Several species recently planted by former inhabitants seem to be appropriate to the area and additional plantings may be used to begin to restore a cultural landscape in the *`Ai`ōpio* area; examples are *hala, kī, kou,* and *milo.* Several native plants already present in the area will benefit from augmentation of their populations and will also contribute to the cultural landscape; several possibilities are *naupaka kahakai, kīpūkai*, and *pōhuehue* on sandy substrate adjacent to the beach and *naio* on the edge of the present *kiawe* forest. One possible theme for restoration of native and Polynesian plants in this area is plants useful for fishing and fishpond activities. Plants with potential uses associated with fishponds include *hala*, coconut, and *hau* (Apple and Kikuchi 1975). *`Auhuhu* (*Tephrosia purpurea*), a Polynesian introduction used as a fishpoison, is another potential outplanting species with interpretive value. In his comments on the General Management Plan (National Park Service 1994b), Herb Kawainui Kane suggested green *kī* and *kou* as traditional plantings to be used around residential structures; such species could be planted in the vicinity of the newly-constructed canoe shed replica. No outplantings are recommended for the area adjacent to *Pu`uoina Heiau.*

Recommendations:

- Introduce appropriate native and Polynesian plants to the *Ai`ōpio* area, starting with the vegetated margin of the beach and the already disturbed former garden site. Possibilities for introduction are *hau*, *`auhuhu*, *kī*, and *kou.*
- Augment the small populations of native and Polynesian plants in the *`Ai`ōpio* area with outplantings of *hala*, *naio, milo, kī, naupaka kahakai, kīpūkai,* and *pōhuehue.*
- Plant several *kī* and *kou* as traditional plantings adjacent to the recently-constructed replica canoe shed.
- Do not outplant additional species on or directly adjacent to *Pu`uoina Heiau.*

Kahinahina`ula or Queen's Bath

Description of features and vegetation. - The anchialine pool known as *Kahinahina`ula* or "Queen's Bath" is a highly modified brackish water pool in *Honokōhau* near the *ahupua`a* boundary with *Kaloko*. It is notable for its associated seven massive *ahu* or rock cairns; these have been variously explained as stations for guards during royal use of the pool, *ahupua`a* boundary markers, or components of a religious complex (Greene 1993). The anchialine pool is one of the deepest in the Park; there is evidence that it has been artificially deepened for human use. There is also the possibility that the pool is completely artificial. In past surveys the "Queen's Bath" was found to contain a diversity of algae, the native red shrimp or *opae`ula* (*Halocaridina rubra*), native snails, and alien top minnows; it was formerly habitat for a rare coelenterate, *Ostromouvia horii* (Chai 1991).

In a recent survey of invertebrates associated with anchialine pools, the candidate endangered orange-back damselfly (*Megalagrion xanthomelas*) was not present at "Queen's Bath", although this species was found at other pools in the vicinity. The past modification of the pool and removal of emergent vegetation, along with the presence of alien fish, are potential limiting factors for the native damselfly (Foote *et al.* in prep.). Currently, vegetation directly adjacent to the pool is sparse, except at its southern bank, where a large Christmas berry and a *pua pilo* shrub are rooted. The Christmas berry overhangs the pool and is certainly adding organic matter to the pool. Away from the pool itself, the *`a`ā* substrate surrounding the pool has very little vegetation other than scattered clumps of fountain grass and a few other alien species. The old *pāhoehoe* substrate to the south of the rock *ahu* is more densely vegetated with fountain grass and is notable as a site supporting the rare endemic sedge *Fimbristylis hawaiiensis*, formerly considered a candidate endangered species (U. S. Fish and Wildlife Service 1990) but now known to be more widespread and numerous than previously documented (Wagner *et al.* 1990). A few scattered *`auhuhu*, a shrub culturally important as a fish poison, are also found in and near the *Fimbristylis* site. The "Queen's Bath" was also the locality of the last Park sighting of the uncommon native grass *Panicum faurei* var. *latius* (*P. nubigenum*) (Canfield 1990), a species not seen in the Park during the last decade.

Current or past vegetation management at site. - There is no current management of vegetation at this site. The nearest active vegetation management projects are the coastal trail to the west and the old *Hu`ehu`e* Ranch Road to the south, which are regularly cleared of vegetation. The *pāhoehoe* substrate south of the "Queen's Bath" is the site of experimental vegetation manipulation ongoing since 1995. As part of a research project to evaluate the effect of fountain grass removal on native plants, fountain grass was mechanically removed from three 5 x 5 m (16.5 x 16.5 ft) plots that contained scattered individuals of the tiny, native sedge *Fimbristylis hawaiiensis*. After two years without fountain grass, the density of the native sedge increased 3-4 fold in the managed plots, while only modest increases were observed in adjacent control plots where fountain grass was left intact (Pratt *et al.* in prep.).

Vegetation management needed to achieve desired condition. - The one large Christmas berry shrub should be removed from the edge of the "Queen's Bath" to reduce input of organic matter from alien species. In this case, the rare orange-back damselfly is absent from the pond and will not be impacted by the loss of shade. An overall strategy of vegetation management should be developed for all the anchialine pools of the Park; this strategy should take into consideration both the native vs. alien status of pond plant species and their functional importance to native pond invertebrates. The natural process of aging and senescence in ponds should also be recognized.

The *pāhoehoe* south of the pool supports the only large concentration of the native sedge *Fimbristylis hawaiiensis* in the Park, and a project to mechanically remove fountain grass from an area 50 by 100 m (165 x 330 ft) will ensure the continued existence of the sedge in the Park and will also be a step toward restoring the original cultural landscape of the pool and associated archaeological features. The two-year-long removal and monitoring research project indicated that the sedge responds positively to active management. The

study also found the level of fountain grass re-invasion to be very low at this site, averaging only 10 new seedlings/plot a year after fountain grass removal. In a management-scale grass removal project, the initial effort to pull the grass will be large, but annual follow-up grass pulling will require little time or effort.

Recommendations:

- Remove large alien Christmas berry shrub on bank of "Queen's Bath" if this action is appropriate to overall anchialine pool strategy in the Park.
- Manually remove fountain grass from the concentration of *Fimbristylis hawaiiensis* sedge south of the pool. The size of the control area will dictate the time required for this project. In the research project, removal of all fountain grass from an area of 25 m^2 took 30-45 minutes. Annual revisits will be necessary to pull new grass seedlings. Herbicides are inappropriate here because they will likely impact the native sedge, and the nearby anchialine pool will be negatively affected.

Restoration of native or Polynesian plants. - As it is unlikely that any significant vegetation cover was present in this area in the early historic period or in the Hawaiian era before European contact, no additional plant species are recommended for outplanting here. However, existing native and Polynesian plant in the vicinity should be conserved. The *pua pilo* adjacent to the pool should be left in place, as should the scattered *`auhuhu* on *pāhoehoe* south of the rock *ahu.* If *`auhuhu* disappears from the site, it will be a good candidate for replacement.

Recommendations:

- Leave existing native and Polynesian plants in place: *pua pilo*, *`auhuhu* and *`uhaloa.*
- Informally monitor *`auhuhu* plants in the area and replace with plants propagated from Park seeds if they disappear from this site.

Anchialine Pools

Description of features and vegetation. - Anchialine pools are ponds near the shoreline with no surface connection to the ocean that exhibit tidal fluctuations and variable salinity; in the Hawaiian Islands they are found only on Maui and Hawai`i, and they are prominent along the *Kona* Coast. Such pools are relatively uncommon and support a distinctive fauna. Unfortunately, anchialine pools have been subject to much disturbance and destruction by development and human use (Maciolek and Brock 1974). More than 30 anchialine pools occur within the Park; there are clusters of pools north of *Kaloko* Pond, just south of *Kaloko* Pond, scattered near the *makai* edge of the large *`a`ā* flow in the center of the Park, and both north and south of *`Aimakapā* Pond (National Park Service 1994b) (Fig. 11). More than two decades ago, the complex of pools near *`Aimakapā* Pond in *Honokōhau* was recognized as a site of "significant aquatic natural value" (Maciolek and Brock 1974). In a more recent study of *Kaloko* Pond and ten nearby anchialine pools of the *ahupua`a*, Chai (1991) found that only one pond was "biologically intact", and the other ponds were rated as low in native species diversity. All the surveyed ponds had the native red shrimp or *`opae`ula* , but fish within the ponds were blamed for reducing the abundance of shrimp and amphipods in most pools. Studies characterizing the insect fauna of the Park's pools are ongoing (Foote *et al.* in prep.). One of the most significant components of many of the Park's anchialine pools is the candidate endangered orange-back damselfly, but a number of other native damselflies, dragonflies, and flies also depend on the pools for breeding and feeding habitat.

Vegetation surrounding anchialine pools is highly variable at Kaloko-Honokōhau NHP. The pools north of *Kaloko* Pond are largely in cracks and crevices in the *pāhoehoe* and support little or no emergent vegetation. Adjacent plants are typically alien species, such as fountain grass, *kiawe*, *ēkoa*, and other alien shrubs. A few native plants occur near some of these northern ponds; *pua pilo* and *`ākulikuli* are visible at a few sites.

South of *Kaloko* Pond, the first anchialine pool complex has several small pools in *`a`ā* substrate with no surrounding vegetation; some of these small pools appear to be artificially excavated. Farther south near the old *Hu`ehu`e* Ranch road is a vegetated anchialine pool that is known to support the candidate endangered orange-back damselfly. This pool (labeled P006, 031 KALO, or pond G by different researchers) has a dense stand of Christmas berry on its western edge and an emergent patch of the indigenous *kaluha* sedge on the eastern side. The area adjacent to the open water on the north and south supports the native coastal species *`akulikuli* and *Fimbristylis cymosa*. North of this pool in *`a`ā* adjacent to the *Hu`ehu`e* Ranch road is a crevice pool where the rare orange-back damselfly has been documented. Vegetation surrounding this crevice pool (apparently unnumbered) is composed of the alien shrubs Christmas berry and sourbush.

South of the *Hu`ehu`e* Ranch road is the highly modified Queen's Bath or *Kahinahina`ula*; this was discussed in the previous section. West of the Queen's Bath and close to the shore, there are several relatively large pools adjacent to the trail to Queen's Bath. The northernmost is densely shaded by *milo* trees; while this vegetation cover has caused some researchers to rate the pond as decadent, the pool provides a shaded area and protective cover for the orange-back damselfly. Two nearby ponds (Chai's ponds H and I) are at an earlier development stage with no emergent sedges and little sediment deposition. The surrounding vegetation of the pond closest to the trail (P010, 044 KALO) is *milo* and Christmas berry on about a quarter of the pool edge and scattered *`ākulikuli* on the rest of the shore. Adjacent to the west is a pool with a dense cover of *milo* on the northern half of the shoreline and only low scattered *milo* on rough *`a`ā* substrate of the southern edge. Neither of these ponds supported the orange-back damselfly when recently surveyed (Foote *et al.* in prep.).

Northeast of *`Aimakapā* Pond is a complex of more than six ponds; this group was noted as biologically and archaeologically rich by Maciolek and Brock (1974). The overstory vegetation near these ponds is dominated by *kiawe*, but the plants surrounding individual pools are varied. Most of the ponds are surrounded by a mixed vegetation, including Christmas berry, sourbush, *`ōhelo kai*, *noni*, *naupaka kahakai*, *`ākulikuli*, and pickleweed. Several ponds have emergent stands of the indigenous sedge *makaloa*, and the deeper ponds support patches of submerged widgeon grass (*Ruppia maritima*), an aquatic flowering plant uncommon in the Park. Mature ponds in this complex contain sediments with a well-developed crust of algae, and floating mats of algae are seasonally present in open water of some of the pools. The orange-back damselfly occurs at this pool complex, and the diversity of native insects associated with the pools is high (Foote *et al.* in prep.).

The anchialine pool resources of the *`Ai`ōpio* area at the southern end of the Park have been less well studied than those near *Kaloko* and *`Aimakapā* Ponds. While Maciolek and Brock (1974) mapped several pools in this area, the recent Park GMP (National Park Service 1994b) noted only the pool complex adjacent to *Pu`uoina Heiau* and a cluster of pools outside the current Park boundary. Other sites in the *`Ai`ōpio* area that may formerly have been recognized as aquatic resources are now vegetated with a dense cover of knotgrass and scattered *kiawe* and *milo* trees; this open vegetation is bordered on the east by a dense *kiawe* forest. The *Pu`uoina* pool complex probably deserves further study; the native red shrimp or *`opae`ula* appeared to be abundant on a recent visit. *`Akulikuli* is prominent on the edges of at least one pool, and there is a large adjacent wetland covered by knotgrass, *`aki`aki*, and a patch of pickleweed. *Kiawe,* sourbush, *naupaka kahakai*, *milo*, and coconut palms grow near the pools and on the edge of the adjacent wetland.

Current or past vegetation management at site. - There are no current vegetation management activities at the anchialine pool complexes in the Park. As some of the pools have clearly been modified for human use by wall construction and deepening, the vegetation of altered pools may also have been removed or greatly changed during the period of modification and heavy use. The pool adjacent to *Pu`uoina Heiau* near *`Ai`ōpio* likely received some alteration of vegetation in recent years when the site and nearby beach supported several residences. The pool complex adjacent to the *heiau* undoubtedly benefited from the general cleanup of trash at the time of *heiau* wall stabilization in 1990 (Johnson and Somers 1991).

Vegetation management needed to achieve desired condition. - Any management of vegetation surrounding pools or emergent vegetation within pools should take into consideration the condition of pools and the goals of the Park in either letting pool development progress to senescence or arresting development at some earlier stage. Some of the pools are in an early stage of development with little sediment development or input of vegetative material. Other pools are partially surrounded by alien vegetation or native *milo* trees; most vegetated pools have a mix of native and alien vegetation. Some flat areas with deep soil beneath *milo* trees near pool complexes may represent former pools now filled in by plant material.

An overall strategy of vegetation management should be developed for all the anchialine pools of the Park; this strategy should take into consideration both the native vs. alien status of pond plant species and their functional importance to native pond invertebrates, including insect species. The natural process of aging and senescence in ponds should also be recognized. Several overall anchialine pool strategies are possible:

1) leave vegetation as is and allow pool development to proceed unaltered, assuming that there is little difference in the impact of native vs. non-native plant species near ponds;

2) select some ponds at which to manage alien vegetation and litter-producing native plant species and designate other ponds to leave alone, with a strategy of maintaining ponds at several development stages within the Park;

3) remove alien and native vegetation to slow down pool senescence throughout the Park.

Strategy 1 is the current situation in the Park. Strategy 3 was suggested for some Park ponds by Chai (1991), who recommended that Christmas berry and *milo* trees be cut and taken away from pond edges and that native sedges be removed to prevent pool in-filling. As emergent vegetation, such as native sedges, and shade from surrounding woody vegetation appear to be important for the survival of the candidate endangered orange-back damselfly (Foote *et al.* in prep), such removal would not be appropriate for pools supporting this and other native insect species. Strategy 2 is a possible compromise between the two approaches, but this can only be undertaken when all Park pools have been mapped, surveyed for their physical characteristics, and monitored for their biological resources.

Recommendations:

- Develop an overall strategy for the Park's anchialine pools, taking into consideration the size, physical characteristics, biological resources (including aquatic invertebrates, insects, algae, and surrounding native plants), and development stage of each pond.
- Do not remove vegetation, either alien or native, until the impact of such management on the pond biota can be evaluated. After an overall Park strategy for pools is developed, it may be desirable to remove both alien vegetation and encroaching *milo* trees from a few pools designated to be managed as early successional examples.

Restoration of native or Polynesian plants. - As the senescence of some anchialine pools may be hastened by the input of leaf litter from adjacent trees and shrubs, it is probably not generally desirable to introduce plantings to sites near pools. However, in pools allowed to undergo natural aging it may be appropriate to replace alien species such as sourbush and Christmas berry with native shrubs and trees. *Pua pilo* and *naupaka kahakai* are possible choices for replacement species, as they are currently established on the edge of some ponds. *Milo*, currently considered a native plant (Wagner *et al.* 1990), is also well adapted to live in and around anchialine pools, but the deposition of copious leaf litter produced by this species may contribute to hastened senescence of pools. If replacement is desired at some pools, the native

plants to be restored should be well established before the alien species are removed, so that shade and protection for native insects inhabiting the pools is not interrupted.

Recommendations:

- Develop native plant outplanting plans for anchialine pools as a part of an overall Park anchialine pool strategy.
- If restoration of native plants is called for at certain pools outplant the native species and allow them to establish before removing alien plants providing shade and protection to pools. Possible choices of native plants to be used in vegetation replacement are *pua pilo, naupaka kahakai*, and possibly *milo* (although *milo* has been implicated as a contributor to pond senescence).

Beaches and Coastal Strip

Description of features and vegetation. - The shores of the northern half of Kaloko-Honokōhau NHP are primarily rocky with sandy substrates just upslope of the often bare rocks. The coastal strip of the southern half of the Park has large sandy beaches along *Honokōhau* Bay and at *`Ai`ōpio* Fishtrap. Strand vegetation is well established along both rocky and sandy shores (Fig. 5), and a number of native plants are represented in the mix of low-growing strand and shrubby strand vegetation types (Canfield 1990). Canfield estimated that 10% of the Park was covered by strand vegetation. The coastline of the northern half of the Park both north and south of *Kaloko* Pond seawall is dominated by tree heliotrope mixed with a suite of alien shrubs and the native *naupaka kahakai*. Scattered native *pua pilo* and *naio* are also found in this shrubby strand vegetation. Although tree heliotrope is native elsewhere in Polynesia, it was first documented from the Hawaiian Islands in 1864-65 and was apparently a cultivated plant in the late 1800s (Wagner *et al.* 1990). Groves of indigenous *milo* occur near fresh or brackish water in *Kaloko ahupua`a*, and coastal *milo* forest, sometimes mixed with *hau* or *kiawe*, is found both north and south of *`Aimakapā* Pond. The beaches along *Honokōhau* Bay support relatively sparse native strand vegetation of *naupaka*, *pōhuehue*, *pā`ū o Hi`iaka*, and other native plants. A few alien grasses and herbaceous plants are also found on the beaches. A dense forest of *kiawe*, mixed with other woody species and grasses, occurs just inland of the strand vegetation (Canfield 1990).

Current or past vegetation management at site. - Past management along the coast involved the removal of woody vegetation from the coastal trail, and current vegetation management consists of maintaining clear conditions along the trail. Mangrove removal at and near *Kaloko* and *`Aimakapā* Ponds in the early 1990s was a major vegetation management project that took place near the coast; this species would have impacted more of the coastal area if it had been left unchecked.

Vegetation management needed to achieve desired condition. - The coastal trail will continue to require periodic maintenance to remove encroaching alien plants and to keep native *milo* trees cut back and limbed where the trail passes through stands of coastal forest. The noxious puncture vine formerly grew along the coastal trail portion of the old *Hu`ehu`e* Ranch Road (Canfield 1990), but the control efforts of the Park staff have been successful at removing the prickly plant from the trail. Periodic monitoring of sites where puncture vine was formerly established will prevent its reappearance. A recent proposal to remove several alien shrubs from a coastal strip stretching from *Kaloko* Pond to the *Kaloko-Honokōhau* boundary involved the cutting, stump treatment with herbicide, and slash removal of *klu*, *ēkoa*, Christmas berry, sourbush, and a few *kiawe* trees. If carried out, this project will be a first step in restoring the cultural landscape of the northern part of the Park's coast. Alien heliotrope trees, prominent in the northern half of the Park shore, are providing shade and should be retained until enough native and Polynesian trees and shrubs are restored to the area near the coastal trail.

Recommendations:

- Continue to maintain the coastal trail by manual removal of alien plants and removal or limbing of native *milo* trees where the trail passes through coastal forest.
- Retain alien heliotrope trees for shade along the coastal trail, until native or Polynesian tree species have been restored to the area.
- Monitor the coastal trail for the reappearance of the noxious puncture vine and manually remove plants, if found.
- Monitor the coast throughout the Park for reinvasion of mangrove and manually remove seedlings, if found.
- Carry out a pilot project to remove alien shrubs from a narrow coastal strip south of *Kaloko* Pond. Herbicide applied as a cut-stump treatment will be required to ensure death of alien shrubs. Obtain clearance to use Roundup for this project, and if permission can be obtained, test other herbicides with known effectiveness on woody plants.
- If successful control of alien shrub species is achieved in the pilot project, expand alien shrub removal to north and south as needed.
- Remove patches of pickleweed along the coast, after an effective control method is developed based on preliminary work at *Kaloko* Pond.

Restoration of native or Polynesian plants. - Several native coastal plant species are already well represented along the Park shoreline. Some of these, such as the coastal sedge *Fimbristylis cymosa,* *ʻākulikuli*, and *ʻōhelo kai*, need no specific management to maintain themselves in large numbers. Other species, such as the relatively common *naupaka kahakai* may be used to replace alien woody species as they are eventually removed to restore a more authentic cultural landscape. Some elements that are relatively uncommon along the Park's shore may be augmented with additional plantings; examples are *naio* and the Polynesian introduction *kou*. Two native coastal species that were documented from the Park by Canfield (1990), but had disappeared by the following survey (Pratt and Abbott 1996b), should be restored to the Park if propagation material can be found in the *Kona* area; these are *hinahina* (*Heliotropium anomalum*) and the tiny annual grass *Panicum faurei* var. *latius*. In the interest of restoring the cultural landscape of the time of Hawaiian inhabitation it is also appropriate to outplant native and Polynesian trees and shrubs that were likely present prior to European contact or during the early historic period. *Hala*, growing just south of the Park (and recently planted at *ʻAiʻōpio*) is a candidate for re-introduction to the Park. *Loulu*, although not documented from the Park in historical times, is likely to have formerly occurred in the Park; the species was noted during historical times near *Kawaihae* to the north (McEldowney 1983) and still grows along the South *Kona* coastline. Recently, *loulu* (*Pritchardia*) pollen has been identified in the pollen record of *ʻAimakapā* Pond (Douglas and Hotchkiss 1998)

Recommendations:

- Use common native species such as *naupaka kahakai* to replace alien plants removed in the Park's coastal area.
- Augment the populations of uncommon native and Polynesian plants already found in the Park's coastal area; examples are *naio* and *kou*.
- Restore native coastal plants that have been recently lost from the Park: *hinahina* and the grass *Panicum faurei*.
- Introduce (or reintroduce) native tree species that were likely original and cultural components of the Park's coastal vegetation; examples are *hala* and *loulu*.

Alien Plant Management at Other Sites

Alien plants that require management at specific sites not included in the list of priority sites and plants that require management throughout the Park are discussed below. If they are suspected to be capable of spreading, localized alien plants that occur in low numbers at few sites should be eradicated from the Park before they become more widespread and unmanageable. Such management should not necessarily be focused on innocuous plant species not known to be invasive elsewhere in the State.

Ivy Gourd (*Coccinia grandis*)

Ivy gourd is a vine in the gourd family that is native to Africa, Asia, and Australia (Wagner *et al.* 1990). Ivy gourd has broadly ovate leaves; showy, bell-shaped, white flowers; and attractive, red, berry-like fruits. The species is dioecious, so male and female flowers are borne on separate plants, and only the female vines produce fruits. Ivy gourd was introduced to the Hawaiian Islands on O`ahu in 1969 as an ornamental, where it was first collected as a naturalized plant in 1985 (Linney 1986). The young fruits and shoot tips of the vine are edible, which may explain why the vine is intentionally spread and planted in new sites. Ivy gourd was first noted in *Kailua-Kona* on Hawai`i Island in 1986 (Linney 1986), and it appears to be continuing to expand its range both north and south. The species was not known from Kaloko-Honokōhau NHP until 1992-93, when seven plants were seen during a botanical survey of the Park (Pratt and Abbott 1996b). Ivy gourd apparently invaded the Park between 1987 and 1992, because it was not seen during the earlier field survey in 1987 (Canfield 1990).

Ivy gourd is a serious pest that has the potential to become much more abundant and widespread within the Park. It will climb into both native and alien trees and may be able to structurally damage the few species of native trees and shrubs extant in the Park. *Naio*, which grows in the *kiawe* forests currently invaded by ivy gourd, may be particularly susceptible to the vine. Ivy gourd also represents a real threat to the integrity of rock walls and other archaeological features within the Park. This pest vine should be immediately eradicated from Kaloko-Honokōhau NHP, while such removal is still possible. Small ivy gourd vines should be uprooted if this will not harm cultural resources. Larger vines may be controlled using a 4% solution of Garlon 4E in diesel oil applied to the base of the stem (Motooka 1989). Areas known to harbor the vine should be systematically searched, and all plants found should be mapped (using a GPS unit, if possible), so that they may be treated and relocated for monitoring. Treated and mapped plants should be periodically revisited and retreated as necessary to completely kill them. Any ivy gourd seedlings found during revisits should be uprooted and destroyed. Monitoring of Park boundaries and periodic searches of suitable habitat will be necessary even after ivy gourd has been eradicated from the Park to ensure that the species does not reinvade from plants outside the Park.

Puncture Vine (*Tribulus terrestris*)

Puncture vine is a prostrate, annual herb with hairy, pinnately compound leaves and small yellow flowers. Its dry fruits are sharply spiny, making this alien species very noxious along trails or in other visitor use areas. The species is native to the Mediterranean region of Europe and has been in the Hawaiian Islands for about 50 years, where it is common on sandy soil in disturbed areas (Wagner *et al.* 1990). Puncture vine was formerly listed as a noxious weed by the State Department of Agriculture (Haselwood and Motter 1966). In the last survey of Kaloko-Honokōhau NHP, puncture vine was found at only one site along the jeep road from the Highway to *Kaloko* Pond; the plants were growing in the middle of the road near its junction with the *Māmalahoa* Trail (Pratt and Abbott 1996b). The weed was formerly present on the beach trail south of *Kaloko* Pond (Canfield 1990). Because of its spines and reputation as a noxious weed, puncture vine has been eliminated from the coastal trail. During recent site visits to the *`Ai`ōpio* area, puncture vine was noted growing on sand adjacent to *Pu`uoina Heiau* (Pratt 1997). The weed should be removed from this locality, as it will interfere with the public's use of the beach, if allowed to spread and intensify. The species is easily

uprooted at the sites of infestation at Kaloko-Honokōhau NHP, and with periodic revisits to former sites, the species may be eradicated from the Park. Monitoring should continue along roads and trails to prevent reinvasion. The seeds are likely being transported on car tires or the soles of shoes. Herbicides are probably not needed to control puncture vine in the Park, but several are known to be effective against the weed (Lorenzi and Jeffery 1987).

Care should be taken to avoid harming the native *nohu* (*Tribulus cistoides*), a related species that belongs in the coastal vegetation of the Park; this native species also occurs along the coastal trail near *Kaloko* Pond. The two species are similar in appearance, but *nohu* plants are taller than puncture vine and have much larger leaves and broader, yellow flowers.

Chinese Banyan (*Ficus microcarpa*)

Chinese or Malayan banyan is a medium to large tree that often starts as an epiphyte on other trees. It has small, shiny, dark green leaves, and its tiny seeds are borne in small, orange figs. The species was introduced as an ornamental plant and as a potential reforestation tree (Hartt 1980); unlike most banyan species in Hawai`i, this one has become naturalized because the necessary pollinating wasp species was also introduced to Hawai`i (Wagner *et al.* 1990). While this banyan is often considered a desirable ornamental, its habit of rooting among the rocks of walls makes it potentially damaging to archaeological features. Only one young Chinese banyan was found within the Park during the last botanical survey of Kaloko-Honokōhau NHP; this individual was growing from a crack in the raised *pāhoehoe* north of *Kaloko* Pond (Pratt and Abbott 1996b). The species appears to be a recent invader, as it was not found in the previous botanical survey of the Park (Canfield 1990); another ornamental banyan species (weeping fig or *F. benjamina*) was noted in an area just outside the Park in 1987, but has not been seen within the boundaries.

The seed source for the one Chinese banyan in the Park is not known, but birds may have dispersed it from landscaping trees in the nearby industrial area. When found, the young banyan tree was cut at the base, but it was later seen with resprouts. This individual should be treated with herbicide to ensure its complete elimination; elsewhere (at Pu`ukoholā Heiau NHS) a cut-stump application of 100% Garlon 3A or 25% Roundup is used to kill this tree (Amerling 1997). Motooka (1995) also found that both glyphosate (Roundup) and triclopyr (Redeem or Remedy) were effective against Chinese banyan when applied to drill holes in the trunk. Banyan should be one of the targets of periodic surveys of roads and trails; only monitoring and consistent control will prevent the eventual re-infestation of the Park.

Autograph Tree (*Clusia rosea*)

Autograph tree, native to the West Indies and Florida, is used as an ornamental in Hawai`i, and has become naturalized at low elevations on Kaua`i, O`ahu, and Hawai`i (Wagner *et al.* 1990). The tree is considered attractive for its thick, shiny leaves and large round capsular fruit, that split open to reveal bright red seeds. The small tree is widely planted in parking lots of *Kailua-Kona* and may be expected to continue to spread to nearby forested areas. Only one small plant was noted during the last botanical survey of the Park; this was growing beside a stone wall separating the beach from the parking lot at *Kaloko* Pond. The same tree was mentioned in the previous Park survey (Canfield 1990). The plant was removed after 1996 and may be considered eradicated from the Park. However, this should be one of the localized alien plants to look for and remove if it reappears within the Park. Because of the proximity of planted ornamental trees and the attractiveness of the seeds to birds, autograph tree is a strong candidate for reinvasion of the Park.

Silver Oak (*Grevillea robusta*)

Silver or silk oak is an Australian tree introduced to Hawai`i in the late 1800s as a potential timber species; it is now naturalized on most of the islands (Wagner *et al.* 1990). While silver oak has beautiful wood

and is much used in furniture making, it is considered to be a pest in rangelands and natural areas (Nelson 1960). The tree is conspicuous because of its shiny leaves with silvery-white undersides and its showy orange to yellow flowers. Only one silver oak tree was found in the last botanical survey of the Park; this was in open shrubland just east of *Kaloko* Pond (Pratt and Abbott 1996b). This species is apparently a new invader in the Park, as it was not observed in the previous survey (Canfield 1990). On a subsequent visit to the site, the silver oak tree appeared to be dead, perhaps responding negatively to dry conditions. No action is needed for this species, other than to confirm its death and prevent its re-establishment in the Park. Should a larger infestation be discovered requiring herbicide treatment, silver or silk oak is killed by the frill application of 2.5% Garlon 4 in diesel oil (Santos *et al.* 1986).

Asiatic Butterfly Bush (*Buddleia asiatica*)

Asiatic butterfly bush or dogtail is an escaped ornamental that has been in Hawai`i for at least 90 years. A shrub with narrow, pointed leaves and long, curved inflorescences of small white flowers, the species is native to Asia and some Pacific Islands (Wagner *et al.* 1990). Only one butterfly bush was found during the last botanical survey of Kaloko-Honokōhau NHP; this was growing beside the unpaved road to *Kaloko* Pond from the Highway (Pratt and Abbott 1996b). It would be prudent to remove this one individual before the species spreads to other sites within the Park. If the plant is too large to uproot, treatment of the cut stump with dilute Roundup or Garlon 3A will likely kill it.

Prickly Pear Cactus (*Opuntia ficus-indica*)

Prickly pear cactus was an early introduction to Hawai`i; it was planted on O`ahu by Francisco de Paula Marin in either 1809 (Wagner *et al.* 1990) or 1818 (Nagata 1985). Native to Mexico, the tree-like cactus was cultivated for its fruits and edible pads, and it was also planted as a prickly hedge (*pānini*). Prickly pear cactus escaped cultivation and is now naturalized on five of the Hawaiian Islands. In recent years the cactus has been considered a range pest, and several biocontrol agents have been released to combat its spread (Davis *et al.* 1992).

During the most recent botanical survey of Kaloko-Honokōhau NHP, prickly pear cactus plants were found on or near five transects and along the road to *Kaloko* Pond (Pratt and Abbott 1996b). While only ten individuals were observed within the Park in 1992-94, there are probably additional plants scattered in open shrubby vegetation. Removal of prickly pear cactus should not be a high priority, but it is likely that this species can be eliminated from the Park by destroying plants whenever they are encountered. The cactus may be killed by cutting and removing the slash, by burning it in place, or by treating it with herbicide (Lorenzi and Jeffery 1987). Herbicides were found to be ineffective on this cactus in Hawaii Volcanoes National Park, where biocontrol agents were introduced to combat it (Tunsion and Zimmer 1992).

`Opiuma (*Pithecellobium dulce*)

*`Opiuma*, a thorny tree from tropical America, was introduced to Hawai`i around 1870 for use as an ornamental. The tree is now well established in the dry lowlands of all the main islands except Lana`i and Kaho`olawe (Wagner *et al.* 1990). It is undesirable because of its thorns and its ability to grow in rocky, dry areas with archaeological resources. While *`opiuma* is not more of a threat to archaeological features than are other woody alien plants in the Park, it is less widespread than some of the other alien shrubs, and it may be possible to eliminate it from the Park or at least greatly reduce its cover in high resource areas. In the 1992-94 botanical survey, *`opiuma* was found infrequently in the northern and southern extremes of the Park, where it typically had <1% cover (Pratt and Abbott 1996b). This species was selected by Park managers for trial removal in a coastal band along the trail south of *Kaloko* Pond. Preliminary results indicate that the shrub is relatively easy to kill with a dilute solution of Roundup applied to the cut stump (Laura Schuster, pers. comm. 1998). Other herbicides, such as triclopyr, have also been found to be effective on *`opiuma* (Motooka

1995). While eradication of this shrubby tree is should not be a high priority for the Park, it should be removed from priority Park sites, along with other alien shrubs.

Molasses Grass (*Melinis minutiflora*) and Buffelgrass (*Cenchrus ciliaris*)

Molasses grass is a mat-forming perennial grass from Africa that was introduced to Hawai`i for cattle forage; it is also naturalized in Central and South America (Hitchcock 1971). The grass is now widespread and common in dry lowlands on all the main Hawaiian Islands except Ni`ihau and is generally considered to be a pest plant for its habit of choking out native vegetation (Wagner *et al.* 1990). The consequences of molasses grass invasion in natural areas are typically an increase in the frequency and severity of fire and the replacement of native vegetation (Hughes *et al.* 1991). On Maui, infestations of molasses grass have been treated with the herbicide Roundup to prevent the destruction by fire of remnant dry forest (Loope *et al.* 1992). Only one patch of this alien grass was found at Kaloko-Honokōhau NHP during the last botanical survey; this was in mixed alien shrub/fountain grass vegetation near the Park's boundary with *Honokōhau* Harbor. This patch of molasses grass should be relocated and killed, as soon as possible. A dilute solution of Roundup (1% in water) will likely be effective in the dry shrubland of Kaloko-Honokōhau (Chris Zimmer, pers. comm. 1998). The treated patch of molasses grass should be periodically revisited and retreated as necessary to completely kill it. The area near the Park's boundary with Honokōhau Harbor should be systematically searched for additional plants of molasses grass, and any found should be treated after removal of inflorescences.

Buffelgrass, a mat-forming, rhizomatous, perennial grass native to Africa and Asia, has been naturalized on Hawai`i Island since the 1930s, and today it is common in disturbed, dry lowlands of most of the main Hawaiian Islands (Wagner *et al.* 1990). At Kaloko-Honokōhau NHP, buffelgrass was seen in the same general area as molasses grass, although it appears to be more widespread within the southwestern corner of the Park. In 1992-94, buffelgrass was noted along the Park/Harbor boundary, along the trail leading into the Park from the Harbor, and at one other site (Pratt and Abbott 1996b). Like molasses grass, buffelgrass should be eradicated from the Park before it has a chance to become well established. Both grasses are potential fire hazards and are known to be able to replace native plant species. While both grasses may have a difficult time competing with the dominant fountain grass in the Park, it is prudent to remove them before they spread farther. At Pu`ukoholā Heiau NHS, buffelgrass is effectively treated with a dilute solution of Roundup or Rodeo in water (Amerling 1997).

Guinea Grass (*Panicum maximum*)

Guinea grass is a large perennial bunchgrass with wide leaves and a large, spreading panicle of tiny flowers. Like many of Hawai`i worst pest grasses, Guinea grass is native to Africa and was introduced to Hawai`i as a forage grass (Wagner *et al.* 1990). This palatable and drought-resistant grass species is still used in cattle pastures of *Ka`ū* and *Kona* (Whitney *et al.* 1964). The large size of Guinea grass and its ability to form dense ground cover beneath *kiawe* trees make it an alien species of concern at Kaloko-Honokōhau NHP. In the 1992-94 survey of the Park, Guinea grass was found to be locally common in *kiawe* forest between *`Aimakapā* Pond and the *Honokōhau* boundary, and a few scattered plants were observed north of *`Aimakapā* (Pratt and Abbott 1996b). Guinea grass may be a relatively new arrival in the Park, as it was not noted in the 1987 botanical survey (Canfield 1990). The grass is probably harmful to archaeological features near *`Aimakapā* Pond.

Removal of the grass now, if feasible, may prevent it from becoming a fire hazard and invader of archaeological sites in the future. It is recommended that informal herbicide trials be carried out in Kaloko-Honokōhau or one of the other *Kona* Parks to test a dilute solution of Roundup or Rodeo against the large grass. Pu`uhonua o Hōnaunau NHP has this grass as a dominant ground cover in the southern part of the Park, and Pu`ukoholā NHS has a small infestation beneath *kiawe* trees north of the *Heiau*. Staff workers at

Pu`uhonua o Hōnaunau have been using Roundup successfully to treat Guinea grass along the 1871 Trail, and they may be able to advise on effective control methods.

Other Localized Alien Plant Species

A number of ornamental species and food plants have been planted near the *`Ai`ōpio* Fishtrap and the area adjacent to *Pu`uoina Heiau.* Several of these non-native plant species are capable of spreading farther into the Park and should be removed as soon as possible; examples of plantings to remove are sisal and wild spider flower. Tobacco has also been recently planted adjacent to *Pu`uoina Heiau*; this plant was an early European introduction to Hawai`i (Nagata 1985), and may not be inappropriate to the historical scene of the Park overall. Tobacco is, however, an inappropriate plant growing directly on the remains of the *heiau.* On a recent site visit to *Pu`uoina*, tobacco had disappeared from the Park without treatment. These ornamental and food species and other out-plantings are discussed in the section on priority sites (*`Ai`ōpio* Fishtrap and *Pu`uoina Heiau*).

The Park has recently received permission to manage a parcel of State Land upon which some of the *Pu`uoina Heiau* pools and several other historical features stand (Laura Schuster, pers. comm. 1998). One of these features is an old salt pan surrounded by ornamental plants. At least one of the alien species planted here, Russian olive (*Olea europaea* subsp. *africana*), may have the ability to spread into the Park and should be removed if possible. The other plantings probably do not represent a serious threat to the Park. These include one eucalyptus tree (*Eucalyptus* sp.), pīkake or jasmine (*Jasminum sambac*), oyster plant (*Tradescantia spathacea*), monstera (*Monstera deliciosa*), agave (*Agave attenuata*), philodendron (*Philodendron* sp.), papaya, and several succulents. Succulents found here are: an *Opuntia* sp., a large *Euphorbia lactea*, *Kalanchoe pumila, K. daigremontiana*, and several plants of uncertain identification. While these herbaceous ornamental plants are unlikely to become widespread pests, they are inappropriate to the site and do not contribute to the historical scene. Manual uprooting and removal will probably be successful with most of these alien species, and the one eucalyptus tree and several small Russian olives may be killed by simple cutting. If mechanical cutting is not sufficient to kill the alien trees, an herbicide effective on woody plants may be required. Garlon 3A is used to kill eucalyptus and Russian olive in Hawaii Volcanoes NP (Tunison and Zimmer 1992).

Succulent ornamental plants were found at one other site within the Park during the 1992-94 survey. A few aloe plants and ornamental *Kalanchoë* were apparently dumped beside a jeep road near the Queen *Ka`ahumanu* Highway in the southern part of the Park. While these had not actually been planted, their succulent nature had allowed them to survive, and they may become part of the Park's alien flora. Such plants will have to be physically removed from the Park to eliminate them.

Ornamental trees and shrubs planted along the Queen *Ka`ahumanu* Highway by the State Department of Transportation are also inappropriate to the scene of the Park. However, the Park does not control this strip of land adjacent to the highway. Park managers may wish to contact the State Department of Transportation and ask them not to plant additional alien ornamentals here.

Two alien plant species reported as noxious in the 1987 botanical survey of the Park (Canfield 1990) do not currently warrant great concern. Hairy honohono (*Commelina benghalensis*) was found rarely northeast of *Kaloko* Pond in 1987, and in 1992-94 the herb was seen only in the southwestern corner of the Park near *`Ai`ōpio*, where it composed <1% of the ground cover in *kiawe* forest (Pratt and Abbott 1996b). This small, creeping herbaceous plant does not seem to be capable of spreading beyond the shady kiawe forest, but it should be monitored periodically to determine its ability to spread and intensify. Indigo (*Indigofera suffruticosa*) was widespread and of occasional occurrence in 1987 (Canfield 1990); in 1992-94, the shrub was found infrequently east of *Kaloko* Pond and in the southern third of the Park (Pratt and Abbott 1996b).

This shrub is already too widespread to eradicate from the Park and should be treated only at priority sites, along with other woody alien vegetation.

Two localized alien plant species that probably have the ability to spread farther into the Park are currently restricted to the Māmalahoa Trail and the entrance road to *Kaloko* Pond. Comb hyptis (*Hyptis pectinata*) and Florida beggarweed (*Desmodium tortuosum*) should be removed from these trailsides and road verges before thay spread to other sites or greatly intensify in number. Both are rank, scraggly shrubs with small, easily dispersed fruits and seeds.

Monitoring and Research Needs

Pili Grass Restoration and Competition Studies

Pili was not known from the Park until three small populations were found during the 1992-94 survey; these grasses were growing among fountain grass and alien shrubs in the northeastern section of the Park (Pratt and Abbott 1996b). *Pili* was probably more common before the invasion of fountain grass, introduced to *Kona* in the early decades of the 20th century and well-established near *Pu`uwa`awa`a* on the slopes of *Hualālai* by 1926 (Degener 1946). After the discovery of the remnant *pili* grass patches in the Park, Hawaii Volcanoes NP researchers established three sets of study plots to evaluate the recovery of *pili* following the manual removal of alien fountain grass. Fountain grass was pulled from three 5 x 5 m (16.5 x 16.5 ft) quadrats containing *pili* grass, and three adjacent plots of 5 x 5 m were used as controls in which fountain grass was left in place. After two years, results of the treatment plots indicate that removal of fountain grass allows *pili* to increase in both cover and density (number of individuals). The mean number of *pili* individuals or clumps doubled within two years of fountain grass removal (Pratt *et al.* in prep.). During the first year after clearing, very few fountain grass seedlings established within the plots. This small study implies that competition with the dominant fountain grass is the most important factor limiting the spread and persistence of *pili* grass within the shrublands of the Park. Park Resources Managers may use the results of this small-scale study to apply to a larger management area in which restoration of the cultural and historic scene (prior to the invasion of fountain grass) is desired. *Pili* grass was mentioned as a potential re-introduction by only one of the respondents to a questionnaire about outplanting and restoration sent to a group of Park advisors in 1997.

The existing patches of *pili* grass in the Park are not at sites highly visible to visitors, and thus interpretation opportunities are limited. Two suggested areas to attempt fountain grass removal and *pili* restoration on a larger scale are: a site near the parking lot and historical remains south and southeast of *Kaloko* Pond and a site between the *Honokōhau* Harbor boundary and *`Aimakapā* Pond. The first site is accessible on the existing entrance road and is near the coastal trail and frequently visited *Kaloko* Pond. The historical and archaeological features here will benefit from the removal of fountain grass, and the presence of *pili* grass is an addition to the interpretive story relating to Hawaiian subsistence. It is unlikely that *pili*, even when well-established, will develop the ground cover now achieved by fountain grass, and it will not be difficult to keep *pili* from invading important sites. While *pili* grass could be restored to sites near the already cleared agricultural planters, it is best that *pili* not be promoted inside or directly adjacent to these features. The second site suggested for fountain grass removal and *pili* restoration is along an old trail leading from *Kealakehe* into *Honokōhau ahupua`a*. This site is east of the existing access trail from the *Honokōhau* Harbor and is south and east of the coastal *kiawe* forest and the *kiawe* encircling *`Aimakapā* Pond. The suggested site contains a *heiau*, petroglyphs, and other archaeological features and is near an archaeological and historical complex beneath the *kiawe* close to *`Aimakapā*.. Removal of fountain grass at this second site will expose petroglyphs to view and allow for the interpretation of the *heiau* and other features. *Pili* grass will be an appropriate addition to this open, dry site, and may be kept from covering features with little effort.

It will be worthwhile to use any *pili* restoration project to answer questions on the most effective restoration techniques. Some important restoration topics are: the comparative benefits of sowing *pili* seeds vs. outplanting plants propagated elsewhere; relative efficacy of manual removal vs. herbicide treatment of fountain grass prior to *pili* restoration; need and frequency of watering; and fertilizer regime. Other questions which may be partially answered by monitoring associated with a restoration project are growth rate of *pili*, phenology of flowering and fruiting, germination requirements of *pili* seeds, and variation among seed lots from different sources. A *pili* restoration project with associated monitoring, analysis, and write-up of results will be of greatest value, as it will share findings with other agencies and individuals interested in *pili* grass restoration. A research project on the potential replacement of buffelgrass by *pili* is underway at Pu`ukoholā Heiau NHS (Daehler 1997), and many of the research questions addressed at that Park may be applicable to the future restoration of *pili* at Kaloko-Honokōhau NHP.

Effects of Fountain Grass Removal on Native Plant Species

In 1995, a small-scale research project was initiated in Kaloko-Honokōhau NHP to investigate the effects of manual removal of fountain grass from the vicinity of eight native plant species: *pua pilo*, *`a`ali`i*, *alahe`e*, *naio*, *naupaka kahakai*, *ko`oko`olau*, the sedge *Fimbristylis hawaiiensis*, and *pili*. After sites supporting native plant assemblages were located within the Park, three fountain grass removal plots and three adjacent control plots were selected for each native plant species. Plots were 5 x 5 m (16.5 x 16.5 ft) in size. Ground cover was measured in each plot before fountain grass was manually removed, and target native plants within the plots were tagged and measured. Plots were re-monitored after one and two years. Fountain grass plants that re-invaded pulled plots were counted and removed at intervals of six months. One general result of all these plots combined was that fountain grass reinvaded very slowly, despite the dense cover of flowering fountain grass surrounding plots and the abundance of fountain grass seeds at study sites. Another commonly seen change in pulled plots was the increase in cover and abundance of non-target native plants, particularly *`uhaloa* and *`ilima*.

Target native plants varied in their response to the removal of fountain grass. Seedlings were noted in the treatment plots of *`a`ali`i, alahe`e*, and *naio*, while no seedlings were observed in control plots or nearby areas. *Pua pilo* seedlings were not recorded in treatment plots, but seedlings were observed near these sites during the course of the study. No dramatic growth was observed in the tagged native shrubs within treatment plots, and the condition of most target natives did not improve noticeably during the study. The most dramatic response to fountain grass removal was exhibited by the uncommon sedge *Fimbristylis hawaiiensis* and by pili grass (discussed above). These two herbaceous species greatly increased in density within treatment plots; *pili* doubled its density and *Fimbristylis* tripled its numbers following removal of fountain grass. *Pili* plants grew rapidly and increased greatly in cover during the study, while the tiny native sedge did not show a significant increase in cover, despite its large gain of individuals within the plots.

This study indicates that removal of the ubiquitous fountain grass may be used to begin restoration of native plants at selected sites within the Park. At least some native plants will increase on their own after fountain grass is removed from their vicinity. The addition of native plant seed sowing, watering and other seedling care would likely enhance the recovery of woody native plants, although such measures do not appear to be necessary for native grasses and sedges when adult plants are present to provide a source of seeds. Several sites within the Park should be selected for fountain grass removal in the interest of restoring the historic and cultural scene of the early 1800s before the arrival and invasion of the alien fountain grass. Restoration sites should meet several criteria; they should be in areas accessible to Park visitors, have Park resources worthy of interpretation, and have assemblages of native plants that can benefit from fountain grass removal and re-establishment of viable plant populations. Areas on the edge of *Kaloko* Pond fit these criteria, as do a number of sites along the coastal trail between *Kaloko* and *`Aimakapā* Ponds. Native plants along stretches of the *Māmalahoa* Trail, particularly *naio, alahe`e*, and *pua pilo*, will also benefit from fountain grass

removal. To these sites could be added the area between the *Honokōhau* Harbor boundary and the dense *kiawe* surrounding *`Aimakapā* Pond; this is described above as a potential *pili* grass restoration site.

Alien Plant Control Methods Research

Most of the current and past vegetation management projects requiring herbicide in the Park have involved fountain grass. In 1996, Roundup and Rodeo (both glyphosate) were the only herbicides used within Kaloko-Honokōhau NHP (National Park Service 1996c); in 1997 the herbicide Garlon 3A (triclopyr) was also proposed for use within the Park (National Park Service 1997b). Roundup is widely used in Hawai`i as a general non-selective control for herbaceous weeds, but it is not specially formulated or labeled for use against most woody plants. Rodeo is the form of glyphosate developed for use in and near aquatic systems. Excepting fountain grass, Guinea grass, and the incipient invader ivy gourd, most of the serious alien plant problems in Kaloko-Honokōhau NHP involve invasive shrubs and trees (Table 2); thus, there is an obvious need for effective herbicides that are specifically designed for woody plant pests and can be used in the Park. Small-scale research on effective herbicides and application methods should be initiated in the Park to define the most effective treatments to control priority alien plant species under the specific conditions of a near-coastal dry site. Such focused control methods research will likely result in the eventual use of the lowest concentration of herbicide, and alien plants will be controlled with the least amount of effort and retreatment. Localized alien plant species probably do not warrant a research program, and can be controlled using more standardized methods that typically work elsewhere in Hawai`i.

Table 2. Invasive Alien Plant Species of Kaloko-Honokōhau National Historical Park

Scientific name	Common name	Current Abundance
Acacia farnesiana	*Klu*	Common in shrublands
Batis maritima	Pickleweed	Common near ponds and on coast
Coccinia grandis	Ivy gourd	Rare in *kiawe* forest and open disturbed sites
Leucaena leucocephala	*Ēkoa, koa haole*	Abundant in shrublands
Opuntia ficus-indica	Prickly pear cactus	Uncommon, potentially invasive
Panicum maximum	Guinea grass	Common near *`Aimakapā* Pond
Pennisetum setaceum	Fountain grass	Abundant throughout Park
Pithecellobium dulce	*`Opiuma*	Common in shrublands
Pluchea symphytifolia	Sourbush	Common near pools
Prosopis pallida	*Kiawe*	Abundant near ponds
Rhizophora mangle	American mangrove	Controlled in wetlands*
Schinus terebinthifolius	Christmas berry	Common
Tribulus terrestris	Puncture vine	Rare on roads/trails

* Essentially eliminated from Kaloko-Honokōhau NHP, but propagules continue to invade Park.

Effective herbicide treatments are known for fountain grass, and workers at Kaloko-Honokōhau NHP have been successful with an herbicide treatment of Rodeo or Roundup applied to vigorously-growing foliage (National Park Service 1996c; Johnson and Somers 1991). Herbicide trials carried out elsewhere on Hawai`i Island indicate that both Roundup (glyphosate) and Velpar (hexazinone) are effective at killing the grass, as is a combination of manual and herbicidal control (Castillo 1997; Tunison *et al.* 1994). While herbicide control

methods research is probably not necessary at Kaloko-Honokōhau, application techniques and combinations of herbicides and manual control may be appropriate topics for investigation. Recently, a Washington State University doctoral student used the Park as a research site to study the physiology of fountain grass, and he has published several papers of interest (Williams *et al.* 1995; Williams and Black 1996).

Other invasive grasses within Kaloko-Honokōhau NHP have vastly less cover than does fountain grass, but Guinea grass is currently of concern near *`Aimakapā* Pond. Guinea grass is controlled elsewhere by using a foliar spray of dilute Roundup (Victor Bio, pers. comm. 1997), and only very small-scale effectiveness testing is likely required at Kaloko-Honokōhau. Other grasses that are incipient invaders (discussed previously) will not require testing, and can probably be eliminated with a treatment of dilute Roundup or by manual methods.

Apart from grasses, the most troublesome herbaceous weeds of the Park are ivy gourd, puncture vine, and pickleweed. Ivy gourd requires immediate control efforts to prevent it from further expanding its range in the Park, but herbicide testing is probably not needed, as Motooka (1989) has already found an effective herbicide treatment for this recent invader in *Kona* (basal bark application of 4%Garlon 4E in diesel). Puncture vine occurs in such low numbers in the Park that it can be removed manually, at least on roads and trails, but should herbicides become necessary, Lorenzi and Jeffery (1987) report that 2,4-D or sulfometuron (Oust) are effective against this weed. Pickleweed is difficult to control with herbicides because of its preferred habitat at the edge of ponds. Park staff members have previously tried using black plastic to cover and kill pickleweed with little success (Laura Schuster, pers. comm. 1997). Elsewhere in Hawai`i, pickleweed is controlled mechanically with bulldozers (Diane Drigot, pers. comm. 1997), a method that cannot be employed at Kaloko-Honokōhau NHP. The most promising control technique for pickleweed is burning with torches; this experimental vegetation management project is described in the following section. Prickly pear cactus, a noxious weed of ranch lands and some natural areas, is too uncommon at Kaloko-Honokōhau NHP to warrant any herbicide testing; this species should be manually removed when encountered.

Alien woody species are the invasive plants most likely to require small-scale herbicide effectiveness testing in Kaloko-Honokōhau NHP. The most abundant and widespread shrub and tree species in the Park are *ēkoa*, *klu*, Christmas berry, *`opiuma*, *kiawe*, and to a lesser degree, sourbush. A summary of some of the herbicide trials that have been carried out for these species is found within the Alien Plant Control Methods Research section written for Pu`uhonua o Hōnaunau NHP. *Ēkoa* is the species that has been most difficult to control in other Hawaiian Parks and Natural Areas, so this species is likely to require small-scale experimentation with herbicides at Kaloko-Honokōhau. The most promising herbicide for use against *ēkoa* is Garlon 4 or triclopyr ester (Kageler 1983; Eldredge and Gardner 1984; Gardner 1985; Motooka 1993).

Klu and *`opiuma* may prove to be easier to control and may require only basic testing to demonstrate that triclopyr ester (Garlon 4), recommended by Motooka (1993, 1995), will be effective at Kaloko-Honokōhau NHP. Possible application techniques (*i.e.* cut-stump vs. basal bark) should be tested to find the most effective and rapid way to treat these shrubs under the specific conditions found at the Park. Christmas berry control methods have been long studied in Florida (Ewel *et al.* 1982), and some research and control efforts have been initiated in Hawai`i (Motooka 1991; Tunison *et al.* 1992). As with *ēkoa, klu*, and *`opiuma*, Garlon 4 has proven to be the most effective herbicide for use in basal bark treatment of Christmas berry. Roundup has also been used successfully as a cut-stump treatment for Christmas berry (Tunison *et al.* 1992). Sourbush differs from these other shrubs in size, longevity, and woodiness. This species is unlikely to require herbicide methods research, as a dilute (1%) solution of Roundup applied to foliage has been found effective (Motooka 1995; Chris Zimmer pers. comm 1997). The only testing warranted is a trial using Rodeo (the aquatic formulation of glyphosate) against sourbush near pond sites.

Like *ekoa, kiawe* may require some control methods research to find the most effective method of killing the trees and preventing resprouting. In the past, *kiawe* trees were cut but not treated with any

herbicide, and large trees usually survived and produced many resprouts. At one point, a covering of black plastic was suggested as a non-chemical means of preventing resprouting, but this method was found to be difficult to apply and had limited success (Laura Schuster, pers. comm. 1996). Ten years ago, the Vegetation Management Specialist at Hawaii Volcanoes NP recommended a 50% dilution of Roundup in water as a cut-stump treatment and a 1-2% solution of Roundup for use against resprouts of *kiawe* (Tunison 1988). Currently the Park has both Roundup and Rodeo approved for use against *kiawe* and other alien woody species at historical and archaeological sites. Hawaii Volcanoes NP has used both 100% Roundup and 5% Garlon 4 in diesel as cut-stump treatments for *kiawe* (Tunison and Zimmer 1992). Motooka (1993) found both 2,4-D and triclopyr ester to be effective against *kiawe* when applied as a 2% solution (of product) in diesel to the basal bark of the trees. A small-scale herbicide trial using either Roundup or Garlon 4 and testing the different application techniques of cut-stump and basal bark would help the Park define the most effective control method and the lowest chemical concentration for use on *kiawe*.

Potential Use of Fire for Vegetation Management

There is little expected use for fire as a management tool for most alien plants in Kaloko-Honokōhau NHP. The dominant fountain grass is known to be well adapted to and stimulated by fire (Smith and Tunison 1992) and most of the invasive alien shrub species in the Park have demonstrated the ability to survive fires and rapidly produce basal resprouts (Smith 1985). The one alien species for which fire is a promising management tool is pickleweed, a salt-tolerant, succulent, mat-forming shrub well established on the shores of *Kaloko* and *ʻAimakapā* Ponds (Pratt and Abbott 1996b). Experimental control of pickleweed was initiated in 1996 on the shores of *Kaloko* Pond; the fire management officer and fire crew of Hawaii Volcanoes NP helped plan the project and carried out the prescribed burn. One section along an inlet on the southern shore of *Kaloko* Pond was selected as an experimental site because it had a dense cover of pickleweed, was easily accessible to the firefighting crew, and was adjacent to a manual control project with a cover of native *makaloa* sedge and *ʻākulikuili* to act as seed sources. The dense pickleweed cover was burned off using hand-held propane torches during a period of low water. Those plants that resprouted from the base were burned again in periodic spot re-treatments at two-week intervals for two months.

Preliminary results indicate that fire is very effective at killing pickleweed and consuming dead weed material. The newly-exposed mud and rock shores are now being used by native birds, particularly the Hawaiian black-necked stilt, and are being colonized by the native succulent *ʻākulikuili* (Laura Schuster, pers. comm. 1998). This experimental project should be continued and expanded to include different portions of the shore of *Kaloko* Pond, as well as patches of pickleweed along the coastline to the south. The most effective burning techniques should be investigated, and the best interval of retreatment should be determined. Additional research topics to be addressed are the efficacy of sowing native plant seeds or outplanting propagated seedlings after the burn and the most effective way to maintain some shores free of vegetation for foraging waterbirds. At the end of the experiment, the results should be presented in a written report, so that other Park Service units may benefit from the research carried out at Kaloko-Honokōhau NHP.

There may be some value to research into the use of fire for hazard fuel reduction of *kiawe* at Kaloko-Honokōhau NHP. *Kiawe* currently forms a dense forest surrounding the two large fishponds and extending in a coastal strip south of *ʻAimakapā* Pond. *Kiawe* removal has been accomplished at several sites on the southern edge of *ʻAimakapā*, and may eventually be an important part of a proposed alien plant control project in the Resources Management Plan (National Park Service 1996b). Once *kiawe* trees are cut, there is a large amount of wood and many branches requiring disposal. Hazard fuel reduction will be addressed when the Park Fire Management Plan is prepared (National Park Service 1996b).

Pu`ukoholā Heiau National Historic Site

Introduction

Pu`ukoholā Heiau National Historic Site (NHS) is a small park of approximately 24 ha (60 a) on the leeward side of Hawai`i Island on the shore of *Kawaihae* Bay in the South Kohala District (Fig. 12). *Kawaihae* Harbor is immediately to the north, and Spencer Beach County Park bounds the Park to the south. Most of the Park is west of the *Waimea-Kawaihae* Highway (State Highway 270), but a parcel containing the John Young Homestead is on the upslope or eastern side of the highway. Pu`ukoholā Heiau NHS (or PUHE) is near *Kawaihae,* the driest region in the State because of its position in a rain-shadow produced by the *Kohala* Mountains and *Mauna Kea.* Mean annual precipitation at *Kawaihae* is 223 mm (8.8 in). Rainfall is seasonal with most rain falling during winter months. Mean monthly precipitation ranges from a high of 50 mm (2 in) in January to a low of 6 mm (0.2 in) in July (Giambelluca *et al.* 1986). Pu`ukoholā Heiau NHS is on *Mauna Kea* Volcano near its interface with the older *Kohala* Volcano, and Park substrates are geologically old. Even though *Mauna Kea* last erupted approximately 4,500 years ago, the substrates of the Park belong to the much older *Hāmākua* Volcanics, 0.27 million years before present (Petersen and Moore 1987). Soil within the Park is classified as extremely stony, very fine, sandy loam of the *Kawaihae* Soil Series. Soils of this series are 51 to 102 cm (20-40 in) deep over *pāhoehoe* with a dark reddish-brown surface layer about 5 cm (2 in) thick (Sato *et al.* 1973).

Legal Mandate

*Pu`ukoholā* was designated a national historic landmark in 1966, and Pu`ukoholā Heiau National Historic Site (NHS) was established in 1972 (Greene 1993). The Park is named for *Pu`ukoholā Heiau*, a massive war temple (*luakini*) built by King *Kamehameha* I in 1790-91(Kirch 1985). The legislative act that created the National Historic Site specified the "historically significant temple associated with *Kamehameha* the Great...and the property of John Young..." as the primary sites within the Park "to restore and preserve" (PUHE files; National Park Service 1989). The goal of cultural landscape restoration in the Park is to recreate the appearance of the area as it was in the 1790s, focusing on *Pu`ukoholā Heiau* and the remains of the house site of John Young, the King's English advisor. John Young moved to the *Kawaihae* area in 1793 and constructed a Western-style house on the site in 1798; several other Hawaiian-style structures were also built at the site (Rosendahl and Carter 1988). The site was inhabited by the Young family for several decades.

Early History and Vegetation

Many early European and American visitors to the Hawaiian Islands, including Captain Cook, passed by *Kawaihae*. Most of the numerous accounts of the area compiled by Greene (1993) refer to the area as treeless and "barren." Archibald Menzies, a botanist with Captain Vancouver in 1793, passed along the western coast of *Kohala* enroute to *Kawaihae* and described the region as destitite of trees or bushes," but he noted the presence of cultivated fields upslope (Menzies 1920). Certainly after the introduction of cattle and goats to *Kawaihae* by Captain Vancouver (Tomich 1986), any remaining vegetation in the area would have been negatively impacted by the growing herds of grazing animals. McEldowney (1983) reported that the lands near the coast at *Kawaihae* were called "*pili*" lands, referring to the prominence of grasses, including but not restricted to the indigenous *pili* (*Heteropogon contortus*). As grasses were important for thatching material, lowland grasslands were maintained by Hawaiians through the use of fire (Kirch 1982). Groves of native trees and Polynesian introductions were also present along the *Kawaihae* shore in the early historic period; land award documents (from 1848) and early accounts mention coconut palms or *niu* (*Cocos nucifera*), *hala* (*Pandanus tectorius*), *milo* (*Thespesia populnea*), *kou* (*Cordia subcordata*), and *loulu* (*Pritchardia affinis*) (McEldowney 1983).

The original vegetation of the area before the arrival of Hawaiians cannot be accurately reconstructed, as there are no nearby relicts of undisturbed vegetation, and early descriptions of the area reflect centuries of Hawaiian inhabitation and the impacts of ungulates introduced in the 1790s. However, it is reasonable to imagine a vegetation of scattered native shrubs and trees in a grassland of *pili* (now generally considered to be native) and other grasses no longer present, such as annual panic grasses (*Panicum* spp.). In areas that today support closed *kiawe* (*Prosopis pallida*) forest, there may have been dry forests of native tree species found elsewhere on the island; possibilities include *lama* (*Diospyros sandwicensis*), *kauila* (*Colubrina oppositifolia*), *wiliwili* (*Erythrina sandwicensis*), and *`ohe makai* (*Reynoldsia sandwicensis*). It is likely that species no longer found nearby, and even extinct species, were part of the original species composition of the area, as has been indicated by pollen analysis at lowland sites on other islands (Athens *et al.*1992).

Existing Vegetation

The current vegetation cover of the Park is predominantly alien; of 104 vascular plant species noted in a recent survey, 67% were alien species (Pratt and Abbott 1996c). The major plant communities are buffelgrass (*Cenchrus ciliaris*) scrub grassland and *kiawe* forest. These are recent plant communities. Buffelgrass was introduced to Hawai`i as a cultivated plant in the 1930s (St. John 1973), and *kiawe* was first planted on O`ahu in 1828 from which it was spread to other islands for cattle forage (Wagner *et al.* 1990). In a survey more than 20 years ago, Macneil and Hemmes (1977) recognized four plant communities within the Park: a dry scrub grassland dominated by buffelgrass and scattered *kiawe*, a closed *kiawe* forest along the coast and in the northern part of the Park, a halophytic community near a brackish pond, and a disturbed roadside community. These communities persist in the Park, but the coastal *kiawe* forest has been reduced in size, and a narrow strip of native strand plants is now found along portions of the shoreline (Pratt and Abbott 1996c). Also new since the 1977 survey are a lawn and numerous plantings adjacent to the temporary headquarters building.

Primary Resources and Resource Zones

The most significant resources of Pu`ukoholā Heiau NHS are *Pu`ukoholā* and *Mailekini Heiau* and the John Young Homestead site east of the Highway (Fig. 13); along with a coastal band along the shoreline, these are rated as the highest priority resource areas in a potential cultural landscape management zone map of the Park (PUHE files). The area just upslope of the *Pu`ukoholā Heiau* and the northern tip of the Park below the highway (an area owned by the State but managed by the Park Service) were designated as significant resource areas, primarily because of archaeological resources. The remainder of the Park, including the southern third near the existing temporary headquarters and most of the Park land upslope or east of the Highway, are considered to be resource areas of limited or unknown significance.

Preserving the Landscape and Viewshed of Pu`ukoholā Heiau

One of the most important aspects of the *P`ukoholā Heiau* as an archaeological site is its highly dramatic position on the "Hill of the Whale," where it dominates the skyline for visitors approaching along the shore. The preservation of this view of the *heiau*, uncluttered by scattered trees in the foreground and a lack of woody vegetation upslope of the temple, is one of the most critical goals of vegetation management within the Park. To illustrate the importance of maintaining low vegetation or barren conditions in the vicinity of *P`u`koholā Heiau*, staff members at the Park Service Pacific Islands Support Office have produced a photograph of the *heiau* as it appears today coupled with a photograph simulating the appearance of the temple with a dense growth of *kiawe* trees upslope (Harry *et al.* 1996). When the *heiau* is overshadowed by trees and no longer dominates the skyline, the site losses much of its impressive power. The artist Herb Kawainui Kane, who had previously made detailed studies of the *heiau*, was asked to suggest vantage points from which *Pu`ukoholā Heiau* was best displayed, and he recommended that the landscape be maintained

in an open, barren condition to conserve the earth colors and protect the dominance of the site when viewed from *makai* (Harry *et al.* 1996).

Viewshed maps of the Park were developed by Pacific Islands Support Office staff, using three key viewpoints at sites near *Mailekini Heiau*, adjacent to the proposed new Visitor Center near the coast, and on the *Waimea-Kawaihae* Highway at the junction of the old defunct road to Spencer Beach Park. One of these maps, based on topographic contours, shows that *Pu`ukoholā Heiau* on its hilltop is visible from most of the Park, and even low-stature vegetation growing on or upslope of the *heiau* along the ridge terminating in the "Hill of the Whale" will be visible from key viewpoints and thus will detract from the importance of the site. A second map demonstrates that vegetation higher up the slope terminating in the "Hill of the Whale" will be visible from key viewpoints only if it reaches a mature height of 3 m (10 ft) or 6 m (20 ft), in distinct zones based on contours and increasing distance from the *heiau.* Harry *et al.* (1996) suggest that the highest visibility zones should be the focus of vegetation management within the Park, where acceptable low-growing native plants or their surrogates are maintained to recreate the historic scene while providing an unobstructed view of the *Pu`ukoholā Heiau.* Most desirable plants for the high visibility zones are native herbaceous plants and low shrubs, for example the vine *pā`ū o Hi`iaka* (*Jacquemontia ovalifolia*), low-stature shrubs of *`ilima* (*Sida fallax*) and *`uhaloa* (*Waltheria indica*), and the grasses *pili* and *kakonakona* (*Panicum torridum*), a species no longer present in the Park.

In this view-oriented scheme for Park revegetation, outplantings of tree species should be limited to sites where such additions will not detract from the visibility of the *heiau* from key points. Adoption of this scheme will still allow restoration of native and Polynesian woody plant species at sites along the coast, at the proposed new Visitor Center, near *Pelekane*, at the John Young Homestead, along the access road to Spencer Beach Park, and along several boundaries where a vegetative screen is desired to act as a visual barrier to decrease the impact of modern developments outside the Park. Low vegetation, such as pili grass and native vines, may be restored to any appropriate part of the Park. The viewshed analysis of *Pu`ukoholā Heiau* NHS indicates that the most important vegetation management tasks are the reduction of alien trees and shrubs, particularly *kiawe*, that currently infest sections of the Park and the prevention of new alien woody species from becoming established.

Strategies of Vegetation Management at Pu`ukoholā Heiau NHS

Alien Plant Control

Pu`ukoholā Heiau National Historic Site is largely covered by alien vegetation; therefore a strategy of Park-wide removal and eradication of widespread alien plants is not currently feasible. However, since restoration of the historical scene is a goal of Park managers, several approaches to alien plant control may be taken to partially achieve the desired goal. The primary approaches to alien plant control at Puukohola Heiau NHS are the removal of alien plant cover from the important archaeological sites that the Park was established to protect and the treatment of encroaching alien plants on trails, the Visitor Center, and other sites to permit Park visitors to view the resources of the Park. The sites that are highest priority for removal of alien plant species are described in the following section on vegetation management in priority sites; the focus of alien plant control at priority sites is the removal of assemblages of alien species rather than the targeting of single species. A second goal of alien plant management is to eradicate particularly noxious species from the Park where practical and to prevent the establishment of additional alien plant species that may prove to be future pests. Examples of noxious plants upon which to focus eradication efforts are puncture vine (*Tribulus terrestris*), a prickly herb that is capable of covering trails and interfering with comfortable visitor use; banyan tree (*Ficus microcarpa*), a relatively recent invader that is potentially damaging to archaeological sites; and pickleweed (*Batis maritima*), a halophytic succulent localized at one wetland site in the Park.

As the vegetation covering most of the Park is alien in origin, it may be necessary to accept certain alien species as surrogates for native structural components of vegetation that are missing or are rare components of the Park (after Harry *et al.* 1996). This does not mean that the goal of restoration of the historical scene of 1790 is to be abandoned, but rather that some species currently widespread in the Park must be temporarily accepted to act as surrogates for missing elements thought to have been present in 1790 and the early 1800s. An example of a likely surrogate plant is buffelgrass to represent the grass species that was present in 1790, probably *pili* grass. While the two grass species are taxonomically very different and do not resemble one another in detail, they are grossly similar, and buffelgrass may fulfil a role as a visual replacement for the almost missing *pili*. The use of buffelgrass as a surrogate for *pili* in the current depiction of the historical scenes in the Park does not preclude experimental reintroduction and augmentation of *pili* in the Park or treatment tests for methods to reduce the cover of alien buffelgrass. It is suggested that other alien plants may also be used as surrogates for natives at Pu`ukoholā NHS until techniques are available to more adequately restore the cultural landscape with native and Polynesian plants (Harry *et al.* 1996).

An Integrated Pest Management (IPM) plan has recently been prepared for Pu`ukoholā Heiau NHS; this document reviews control methods for insect pests, rodents, and alien plants in the Park (Amerling 1997). While the alien plant section is very thorough with regard to the most important species to target for control, a scheme of prioritization of alien plants is lacking. It is recommended that a prioritized list of alien plant species be developed for the Park as a first step in developing an overall alien plant management strategy. Reasonable categories of alien plants in this priority list are species to be controlled only in priority sites, localized alien species to be eradicated or controlled Park-wide, invasive species to be prevented from establishing in the Park, and ornamental species to be removed from inappropriate sites. If possible, alien plant species (or suites of species) should be prioritized for importance and urgency of action within these categories. (See Appendix A.)

Concerns about herbicide use expressed for the other two *Kona* Parks also apply at Pu`ukoholā Heiau NHS. Great care should be exercised with regard to herbicide use near the one Park wetland, as well as near the ocean shore. Only herbicides approved for use in wetlands should be applied to pickleweed and other alien plants in and near the brackish pond within the Park. Park personnel using herbicides should be adequately trained (as is currently the situation), and all National Park Service regulations, State agricultural laws, and label restrictions should be followed within the Park. The Park should continue to keep a log of herbicide use and maintain good records of management activities.

Native Plant Management and Restoration

General strategies for native plant management and restoration - As all of Pu`ukoholā Heiau NHS is within a cultural management zone (PUHE files), the objectives of vegetation management here are primarily maintaining the historic scene and protecting the cultural resources of the Park (National Park Service 1988). The primary goal for vegetation management in Pu`ukoholā Heiau NHS is the manipulation of vegetation to reflect the historic/cultural scene as it was in the 1790s, the period of the construction and use of *Pu`ukoholā Heiau* and the John Young Homestead. Inherent in this goal is the protection of the important archaeological resources of the Park. As most of the Park is covered with alien plants introduced long after the historic period of the 1790s, restoration of the cultural landscape will require the removal of some alien species and the restoration or reintroduction of native and Polynesian plant species known from the Park or appropriate to the dry lowland site. Native species already in the Park will benefit from augmentation of their numbers, and other species appropriate to the area but not currently found within Park boundaries may be introduced. *Pili* grass falls into the augmentation category, and the lowland grass *kakonakona* is an example of an appropriate species no longer found within the Park, but deserving of introduction.

As the cover of most alien plant species is far too great to allow for total eradication from the Park, the focus of alien plant removal should be priority sites within the Park. Following alien plant removal,

restoration of native vegetation should be attempted at priority sites, if feasible and appropriate. At some priority sites discussed below, there is no justification for any reintroduction or outplanting because plants were not part of the historic scene and/or they would be damaging to archaeological sites if planted nearby. In most cases, there is not enough documentation to allow for the complete restoration of sites, because it is not known with certainty what native species grew there. However, at a few priority sites, the augmentation or reintroduction of native plants will enhance the cultural landscape; examples are *Pelekane*, the coastal strip of the Park, the John Young Homestead, sections of the old Spencer Beach Park road that are to be removed, the proposed new Visitor Center, and several key points along Park boundaries.

There is probably little possibility of restoring large numbers of native plants throughout the Park with current levels of staffing and funding. Given our lack of understanding of the vegetation cover in 1790, such restoration would not greatly contribute to the primary goal of restoring the relatively sparsely vegetated cultural scene of the 1790s. However, large-scale replacement of the alien buffelgrass with the indigenous pili grass may be possible following the development of buffelgrass control methods and the successful completion of an ongoing research project on pili restoration.

Several criteria should be used in the selection of native and Polynesian plant species to reintroduce to priority sites within the Park. Native and Polynesian species should be used exclusively for outplanting, as it is inappropriate to introduce alien plant species to a cultural (or natural) zone of a National Park (National Park Service 1988). Revegetation should use only those species present at the time of the historic scene to be restored (National Park Service 1993a); in the case of Pu`ukoholā Heiau NHS, this means native lowland species and Polynesian introductions typical of a coastal site. Alien species are justified for outplanting only if there is good documentation of their presence at the site in the 1790s. This is unlikely, as there were relatively few alien plant species introduced in the period between 1778 and 1790 (Nagata 1985). Native and Polynesian species should also be appropriate to the site in which they are planted; coastal species should be planted only near the coast and lowland species of wider distribution should be used for other Park sites. Species found naturally only at higher elevation or in wet habitats should not be considered for outplanting at Pu`ukoholā Heiau NHS. In general, species to be reintroduced or augmented should be part of the historical scene and contribute to the interpretation of the Park's primary resources.

Management strategies for existing native plants. - Native plant species make up only 20% of the Park's existing flora, and Polynesian introductions are another 13% of the current flora (Pratt and Abbott 1996c). Among the 20 endemic or indigenous plant species found in the Park during a survey in 1992-94, 12 species appeared to be naturally occurring, although there is some chance that a few of these were intentionally planted in the past. Most of these native plants were found along the coast or in a wetland at the opening of a dry gulch. The indigenous shrub species *`ilima* and *`uhaloa* were noted throughout the Park. Other native plants, particularly rare species, were present only as plantings near the Visitor Center.

Naturally-occurring native plants should be conserved wherever possible within the Park. They should not be intentionally removed from an area unless they are harming archaeological features. If native plants are growing on features and pose a threat to site integrity, they should be removed. Such removal is justified in a cultural zone of a Park if the native species in question are not rare. Such removal is unlikely to be necessary very often, and each species to be removed should be evaluated for rarity and occurrence elsewhere in the Park before action is taken. Polynesian plant species should also be conserved when they contribute to the historical and cultural scene. Inappropriately planted native and Polynesian species should be removed, preferably by transplanting; preventing the death of transplants is particularly important in the case of rare native species.

Monitoring of naturally-occurring native species is a means of determining the status of the species in the Park. Simple counts of individuals or measurements of cover in relocatable plots repeated at intervals of several years will allow an assessment of how the native species are faring in the Park. Outplanted native

or Polynesian species should be monitored for survival, vigor, and growth until they are clearly established to help assess the effectiveness of the outplanting techniques and to refine the overall outplanting program. Permanent records should be maintained on all outplanted species, and the loss of individual plants should be recorded. To assist future Park managers, the fate of outplantings should be recorded.

Management strategies for outplantings of native species. - Suggestions for native and Polynesian species to outplant are given in the restoration section of each of the priority sites discussed below. Criteria for selection of species to plant are appropriateness to the area planted and enhancement of the historical/cultural scene. Emphasis should be on common native plant species where possible, because these are usually easier to obtain and to propagate, and they will be most likely to survive. *Pili*, other native grasses, and low-stature native shrubs are good candidates for restoration projects. Rare native plant species should be introduced to the Park only if there is good historical or biological information to support such an introduction. The Park should not evolve into an arboretum of interesting rarities that have no direct relation to the Park's primary mission. Those endangered plant species that have already been placed in the Park should be cared for, and the Park should apply for a State Endangered Species permit to possess the endangered *loulu* and *ma`o hau hele* (*Hibiscus brackenridgei* subsp. *brackenridgei*). A Federal Endangered Species permit is not required, because the plants were derived from cultivated material.

Guidelines for outplanting may be found in National Park Service directives (National Park Service 1993a) and unpublished reports of other Parks (Hawaii Volcanoes NP) and other agencies (Woolliams and Llop 1993). Seed collection guidelines should be developed along with the outplanting program. In general, seeds should be obtained from the nearest natural source, to take advantage of possible local site adaptations. Seeds should not be collected far in advance of the time they will be sown or germinated; long-term seed storage often results in loss of viability (National Park Service 1993a). The source of any seed used in Park outplanting programs should be recorded in permanent Park files. Propagation guidelines should also be developed for the Park outplanting program. Generally plants should not be purchased from commercial nurseries or private growers without proper documentation of the source of the seed and the propagation techniques used. Likewise, plants without documentation should not be accepted as gifts from private individuals. The Amy Greenwell Ethnobotanical Garden should be considered as a site for propagation of native and Polynesian plants for the Park, using seeds collected by Park personnel or designated collectors with the proper technical expertise to identify plants and properly care for seeds. The Garden has a Memorandum of Understanding with the three *Kona* National Historical Parks to accomplish such plant propagation work.

Material to be outplanted in the Park should be healthy and free of disease or insect pests (National Park Service 1993a). Plants propagated for the Park should be raised in sterile potting medium from which the upper half inch of soil is removed immediately before outplanting. Plants should be decontaminated with acceptable pesticides at least two weeks before outplanting to remove any plant pests, including nematodes and scale insects. Growth and survivorship of outplanted individuals should be monitored periodically. Records of species outplanted, seed sources, treatment regime, and fate of outplanting should be kept within the Park. Similar guidelines for seed collection, propagation, and outplanting have been developed and adopted by Resources Managers at Hawaii Volcanoes NP (Tunison 1996).

Vegetation Management in Priority Sites

Pu`ukoholā Heiau NHS is a relatively small Park containing highly significant archaeological and cultural features. While the entire Park is worthy of receiving vegetation management attention, the following nine sites are particularly deserving of focused effort to remove alien plants and restore native plants to achieve the historical scene of the 1790s. All but one of these sites, the proposed new Visitor Center, are currently receiving some level of vegetation management. The highest priorities among the nine sites are *Pu`ukohola* and *Mailekini Heiau*, the John Young Homestead, trails used by visitors to visit the Park, and the

existing Visitor Center. The following sections report current management activities at each of the priority sites and describe additional alien plant control or native plant restoration projects to enhance their condition.

Pu`ukoholā and Mailekini Heiau

Description of features and vegetation. - *Pu`ukoholā Heiau* is one of the largest and most important heiau in the Hawaiian Islands (Kirch 1985). This war temple or *luakini heiau* was built by *Kamehameha* I during his attempt to become the supreme ruler of the Hawaiian Islands, as a result of a prophecy that a temple at *Pu`ukoholā* dedicated to the war god *Kuka`ilimoku* would result in his conquering all the islands (Greene 1993). The construction of the *heiau* was begun in 1790 and was interrupted periodically by warfare. The dedication of the temple took place in 1791 and involved multiple human sacrifices, including Chief *Keoua Kuahu`ula*, *Kamehameha*'s primary rival on Hawai`i Island (Apple 1969). *Pu`ukoholā* was apparently the last large *heiau* constructed in the Hawaiian Islands, and a number of contemporary written accounts provide information about this site (Greene 1993). The *heiau* is also one of the best preserved religious sites on the island. Constructed on the most imposing hill of the area, 39 m (130 ft) above sea level with a sweeping view of *Kawaihae*, the *Pu`ukoholā Heiau* is composed of a massive stone wall, three terraces, and interior platforms and paved terraces (Kikuchi and Cluff 1969). Stokes, who surveyed the *heiau* in 1906, remarked on the use of weatherworn stones or *`alā* as a veneer over more typical rough stone construction (Stokes and Dye 1991). While Stokes found the site of the *heiau* much disturbed in the first decade of the 20th century, later archaeological surveys indicated that the temple structure was in good condition for a site that had been abandoned for almost 200 years (Ladd 1986b; Kikuchi and Cluff 1969). Ladd (1986b) speculated that portions of the central courtyard and temple platform had been restored in the 1920s.

While a number of descriptions of the site were written in the 1800s, none of them presents any real discussion of the vegetation of the area, other than to call it barren. For example, William Ellis visited John Young and toured the *Pu`ukoholā Heiau* in 1823, and his account of the site fills three pages of his journal but does not mention a single plant (Ellis 1969). One illustration of *Pu`ukoholā* (and *Pelekane*) made by Duperrey in 1819 (reproduced in Greene 1993) shows no trees or shrubs between the coast and *Pu`ukoholā Heiau* on its prominent hill. By 1906, *kiawe*, a tree introduced to the Hawaiian Islands in 1828 (Wagner *et al.* 1990), was prominent in photographs of *Pu`ukoholā Heiau* (Stokes and Dye 1991). As is true today, in 1906 a dense cover of *kiawe* was present along the coast downslope of *Pu`ukoholā* and *Mailekini*, but only scattered trees were present in the area adjacent to the *heiau*. The lack of vegetation on the ground surrounding the *heiau* and the absence of lower branches on *kiawe* trees in the 1906 photographs indicates that the area was being heavily grazed by either cattle or goats. Unlike current conditions, there was almost no grass present in the 1906 photographs, and the ground was largely bare soil and rocks with scattered unidentifiable low shrubs in a leafless condition.

Except for an increase in grass cover, vegetation in the immediate vicinity of *Pu`ukoholā Heiau* did not change drastically between 1906 and approximately 1970. Photographs of the site taken before 1969 (Kikuchi and Cluff 1969) show a dense cover of *kiawe* near the shore below *Pu`ukoholā* and *Mailekini Heiau* and scattered *kiawe* and a ground cover of grass surrounding *Pu`ukoholā*.. Macneil and Hemmes (1977) characterized the vegetation surrounding the *heiau* as scrub grassland of buffelgrass and *kiawe*, and the area remained dominated by these species in the early 1990s (Pratt and Abbott 1996c).

Mailekini Heiau is located just downslope (52 m or 170 ft) of the larger and more imposing *Pu`ukoholā Heiau* (Fig. 13). *Mailekini Heiau* is thought to be an ancient structure. Apple (1969) reported that it was the principal temple of the chiefs of *Kohala* in the 1780s, prior to the construction of *Pu`ukoholā Heiau*. Located on the lower slope of the "Hill of the Whale," the narrow rectangular *heiau* was built on land artificially leveled and filled. The remaining structure of the *heiau* consists of a massive wall on the north, south, and east and a lower, possibly older, wall on the western *makai* side. Within the walled enclosure are a ditch along the western wall; a dirt floor and paved raised platform at the southern end of the structure; a pavement, wall, and

path in the central section; and a disturbed area in the northern part of the *heiau* (Kikuchi and Cluff 1969). In the early 1800s, *Mailekini* was used as a fort by John Young, who placed 21 cannon on the *heiau* to protect *Kawaihae* and the King's residence; this likely disturbed the original rock construction of the site (Apple 1969). Later in the 19th century, *Mailekini* was used as a burial site, and much of the rock work was altered when stones were taken from the *heiau* walls to build at least 11 graves (Cluff 1969).

Bishop Museum photographs dating from the turn of the century show the area immediately surrounding *Mailekini Heiau* devoid of any major woody vegetation, resulting from either intentional clearing or the effect of grazing animals; a dense cover of *kiawe* appears just downslope of the *heiau* (Stokes and Dye 1991). Little vegetation appeared to be growing on *Mailekini* in 1906 other than scattered grasses and low shrubs; a few scraggly, nearly dead *kiawe;* and one large prickly pear cactus (*Opuntia ficus-indica*), a species no longer present within the Park. The current vegetation on the surface of *Mailekini Heiau* is a very sparse scattering of buffelgrass, Australian saltbush (*Atriplex semibaccata*), hairy abutilon (*Abutilon grandifolium*), the possibly native vine *Merremia aegyptia*, and *`ilima*. After periodic herbicide treatment, the surface of the ancient structure is essentially bare of vegetation.

Current or past vegetation management at site. - The structure of *Pu`ukoholā Heiau* may have been cleared of vegetation during archaeological survey work in 1969. Photographs of *Pu`ukoholā Heiau* taken during the survey project show small shrubs, possibly *kiawe,* growing on the walls and a sparse cover of grass on the central platform (Kikuchi and Cluff 1969). Stabilization and reconstruction of broken and weakened walls of *Pu`ukoholā Heiau* was undertaken in 1978; before and after photographs show that scattered *kiawe* and other shrubs were removed from the outer walls and terraces, and a cover of unidentifiable grass (probably buffelgrass) was pulled from interior pavements and platforms (Ladd 1986b). Current vegetation management of the structure of *Pu`ukoholā Heiau* involves the herbicidal treatment of any plants encroaching upon the site. A dilute solution of Roundup in water is used to kill these mixed alien grasses, herbs, and shrubs, and this project requires approximately 6 partial days per year (Amerling 1996). In 1996, treatment of the site was carried out monthly between September and March, but no management was needed during the dry summer months. Wet years result in greater growth of alien plants and as much as 25% more effort may be expended in vegetation management (Peter Amerling, pers. comm. 1997).

Mailekini was also surveyed in the 1960s, and encroaching alien vegetation was likely removed from the structure at that time (Kikuchi and Cluff 1969). As at *Pu`ukoholā Heiau*, current vegetation management at *Mailekini* consists of periodic treatment of the site with the herbicide Roundup to remove mixed alien grass, herb, and shrub species from the ruins of the *heiau*. This treatment required approximately 7 partial days in 1996. During late fall and winter months, treatment of *Mailekini Heiau* was carried out approximately once a month, but no herbicidal treatment was necessary during the summer (Peter Amerling 1996).

Vegetation management needed to achieve desired condition. - As *Pu`ukoholā* and *Mailekini Heiau*, along with the John Young Homestead, are the most significant features of the Park, the most important goal of vegetation management at these priority sites is the periodic removal of alien vegetation (and occasionally a native shrub such as *`ilima* or *`uhaloa*) that encroaches upon the temples. If left untreated, these plants would obscure the features and eventually damage the integrity of the massive stone structures. It is also highly desirable to prevent *kiawe* and other alien woody species from encroaching too near the two *heiau* and interfering with the imposing view of the sites. It is particularly important to retain visibility of *Pu`ukoholā Heiau* from key viewing sites along the coastal trail and near the proposed new Visitor Center (Harry *et al.* 1996).

Recommendations:

- Continue to treat encroaching alien vegetation on *Pu`ukoholā* and *Mailekini Heiau* with periodic applications of the herbicide Roundup.
- Continue to remove kiawe trees in the vicinity of the two *heiau* to preserve the imposing view of the sites from the coastal trail and site of the proposed new Visitor Center.

Recommendations (Continued):

- Eradicate the noxious puncture vine from trails near the two *heiau* and from the area near the *lele* associated with *Pu`ukoholā*.

Restoration of native or Polynesian plants. - There is no historical evidence that plants were a feature of *Pu`ukoholā* or *Mailekini Heiau*, and any growth of plants on the two *heiau* will potentially damage the structure of the features. Woody plants should also be minimized in the area immediately upslope and adjacent to *Pu`ukoholā Heiau* to preserve the imposing view of this most important Park feature. The area between the two *heiau* was likely free of woody vegetation during the time of construction and use of the *heiau*, and the current vegetation should be maintained as low herbaceous growth. As the dominant ground cover in this area is now the alien buffelgrass, it is desirable to replace the alien grass with the native or Polynesian *pili* in the relatively small area between *Pu`ukoholā* and *Mailekini*.

Recommendations:

- Do not plant woody species in the immediate vicinity of *Pu`ukoholā* and *Mailekini Heiau* or upslope of *Pu`ukoholā*.
- Replace buffelgrass with native *pili* in the area between *Pu`ukoholā* and *Mailekini Heiau* after the results of experimental pili grass restoration elsewhere in the Park are available.

Pelekane

Description of features and vegetation. - *Pelekane*, which is a Hawaiianization of the word "Britain" or "British" (Greene 1993), is the site of a complex of houses used by the Hawaiian royal family and high chiefs during the time of *Kamehameha* I. *Pelekane* is also important as the putative site of the murder of the high chief *Keoua* and the place at which *Kamehameha* I became king of the Hawaiian Islands. The site is located north of *Mailekini Heiau* upslope of the shoreline and the brackish pond; the trail from the coast to the John Young Homestead passes through the *Pelekane* area (Fig. 13). Despite the archaeological importance of the site, no specific archaeological survey work has been done in the area. Some preliminary work, including excavation and analysis of subsurface features, is essential to the understanding of how the area was used and what its appearance was during the critical time period of the 1790s (Laura Schuster, pers. comm. 1996). A illustration of the area made in 1819 shows grass houses of the king's residence and other nearby lesser structures; several accounts from the early 1800s also describe the grass houses of the site (Greene 1993).

Many physical changes have taken place at this site in the last 200 years. The coastline near *Pelekane* was drastically changed with the development of the *Kawaihae* Harbor facility and the creation of a large landfill of dredged coral in the 1950s. *Pelekane* was formerly closer to the shoreline, and fishponds that originally occurred near the site have been completely lost. Apparently, a concrete well once existed at *Pelekane* that served the people of *Kawaihae*, but no trace of this water source remains. In the 1960s a concrete plant was placed in the *Pelekane* area; this industrial use must have resulted in considerable disturbance, although no obvious sign of the plant remains at the site. Earlier uses of the area included a railway and charcoal production, and the old King's Trail once passed through *Pelekane* (Greene 1993). The construction of a road and later a railway must have resulted in significant site disturbance here, and trees and other plants were likely kept clear of the road and rail bed.

The vegetation at *Pelekane* has also changed greatly in the last 200 years. One illustration of *Pelekane* (and *Pu`ukoholā*) made by Duperrey in 1819 (reproduced in Greene 1993) shows no trees or shrubs between the coast and *Pu`ukoholā Heiau.* The grass houses illustrated in this picture have no obvious plantings around them, and no grasses or other ground cover are depicted. *Pelekane* currently consists of a relatively flat terrain vegetated with tall *klawe* trees and a ground cover of alien grasses and herbs. Stone walls are visible at the site, but some of these may represent sites of relatively modern house

sites (Greene 1993). There is little evidence of remains from the period of use as a royal residence. Plant species composing the current ground cover at *Pelekane* include buffelgrass, salt bush (*Atriplex* spp.), and a few other herbaceous weeds. A few native *pā`ū o Hi`iaka* vines grow naturally in the area. In 1996, several Polynesian crop species and a few native plants persisted from earlier plantings on the north side of *Pelekane*; these were *`uala* or sweet potato (*Ipomea batatas*), *ipu* or bottle gourd (*Lageneria siceraria*), *kī* or *ti* (*Cordyline fruticosa*), *wauke* (*Broussonetia papyrifera*), *kō* or sugarcane (*Saccharum officinarum*), *naupaka kahakai* (*Scaevola sericea*), *milo*, *hala*, *pili*, and the endangered *ma`o hau hele*. Several other species that had been planted at this site during the last decade did not survive; these included *`a`ali`i* (*Dodonaea viscosa*), *`ilima*, and *kou* (Peter Amerling, pers. comm. 1996).

Current or past vegetation management at site. - Past uses of the site before the establishment of Pu`ukoholā Heiau NHS were very disturbing to the vegetation and the cultural resources of *Pelekane*. Clearing of *kiawe* and burning of slash have been carried out at a site near *Pelekane*, and this project continues as part of a hazard fuel reduction program (Jack Minassian, pers. comm. 1998). Current vegetation management at *Pelekane* involves the used of the herbicides Roundup and Rodeo (both glyphosate) to remove alien ground cover of mixed weed species and retreatment to prevent re-invasion. Spraying ground cover weeds required portions of 5 days in 1996 (Amerling 1996); treatments and retreatments were done monthly September through November, and also required a day in January. *Mauka* of *Pelekane*, *kiawe* stumps were treated with the herbicide Garlon 3A to prevent resprouting after trees were cut in a project to reduce *kiawe* tree cover and thus lessen flammable woody fuels in the Park. This *kiawe* control took 6 days in October and November of 1996. The native plant project near *Pelekane* required 3 days in 1996 to treat alien weeds with the herbicide Rodeo. Care of past outplantings of native plants at this irrigated site near *Pelekane* required an unknown number of days; without irrigation most of these outplantings would not survive (Peter Amerling, pers. comm. 1996).

Vegetation management needed to achieve desired condition. - There are two primary considerations in determining the desired appearance of the vegetation at *Pelekane*. The only documentation we have for the historical scene indicates that vegetation of any kind was not a prominent feature of the site. However, the desired use of the area is as a gathering place for groups of people who will sit on the ground and practice crafts or meet for other purposes. This need requires hardy herbaceous plants that will provide a cover over bare soil and will reduce the possibility of windblown dust and sand (Daniel Kawaiaea, pers. comm. 1996). Shade is also desirable to make human activities more pleasant in this hot area. The current sparse ground cover of buffelgrass and weeds is not sufficient for the desired use of the area. A better grass cover is needed for the relatively flat site to be used for gatherings. While restoration of the native *pili* grass is preferred at this site, alien grasses such as Bermuda grass (*Cynodon dactylon*) may have to be planted if *pili* will not grow.

It is desirable to remove the alien *kiawe* trees from *Pelekane*, but this should not be attempted until some native or Polynesian tree species have been planted to provide shade for the time when the *kiawe* are removed. Before any outplanting can be done, the site must first be surveyed for archaeological resources. Native species to be planted as shade trees should be propagated and allowed to grow beyond the sapling stage well in advance of any landscaping project at *Pelekane*.

Further plantings of crop plants or native shrubs should not be made in the currently irrigated area to the north of *Pelekane*, until archaeological work can be carried out on sub-surface features at the site. Extensive planting of trees and shrubs with deep root systems could damage unseen features beneath the ground surface before archaeologists have an opportunity to evaluate them and learn more about the historic and prehistoric uses of the area. The sowing of grass seed here, whether of the native *pili* or an introduced surrogate, will probably not interfere with future archaeological work at the site.

Recommendations:

- Sow seeds of *pili* grass or plant bunches of *pili* grass on the flat area at *Pelekane* to provide a more pleasant ground cover for gatherings at the site. Use the results of ongoing *pili* grass research to help guide outplanting technique. Use a local source for seeds, perhaps the recently discovered patch of *pili* near the existing Visitor Center (Daehler 1997).
- If *pili* grass is impossible to restore at *Pelekane*, sow seeds of an acceptable alien substitute, perhaps the salt-tolerant Bermuda grass, which is already present in the Park at the existing Visitor Center.
- Remove alien *kiawe* trees currently providing shade at *Pelekane* only after native or Polynesian tree species are available for outplanting at the site.
- Do not plant any additional species at the garden site just north of *Pelekane* until preliminary archaeological investigations can be carried out at the site.
- Continue *kiawe* reduction and the use of prescribed fire near *Pelekane*.

Restoration of native or Polynesian plants. - There are several ongoing or proposed projects at *Pelekane* that involve the restoration of native or Polynesian plant species. Replacement of alien buffelgrass with the native *pili*, so that the bare dirt can be stabilized and dustiness reduced, is a desirable project to be undertaken in the near future. Replacement of *kiawe* trees with native shade trees is also proposed to allow for the removal of the alien tree without the loss of shade at a gathering site for groups at *Pelekane*. The native plant project that has resulted in the successful outplanting of approximately ten native and Polynesian plant species should not be expanded until archaeological work can be accomplished at *Pelekane*. Restoration of native and Polynesian tree and shrub species to the shore adjacent to *Pelekane* should continue after archaeological evaluation of the site.

Recommendations:

- Same as first recommendation of previous section; restore *pili* grass to *Pelekane*.
- Propagate native shade trees for eventual outplanting at *Pelekane* after *kiawe* tree removal. Species to start with are *milo, hala*, coconut and *hau* (*Hibiscus tiliaceus*). The latter species will be a new introduction into the Park, but can be justified as a common native plant that would be likely in a coastal site, particularly one inhabited by Hawaiians who made extensive use of the wood and bark of the species.
- Plant no more species at the irrigated native plant project site north of *Pelekane* until archaeological investigations are completed. Keep existing outplantings that are appropriate to the area alive with watering and other necessary care
- After archaeological excavation at and near *Pelekane*, plant additional native tree and shrub species near the shore. Suggestions for appropriate species are *milo, hala, hau*, and *loulu*. The *loulu* palm of dry coasts on Hawai`i Island is a listed endangered species and will require permits and particular care to ensure survival.

Coastal Strip, Trail, and Wetland

Description of features and vegetation. - The coastal strip below the old, now disused road, stretches north from the boundary with Spencer Beach Park to a sandy beach along the small bay adjacent to the coral fill of the *Kawaihae* Harbor complex (Fig. 13). The northern part of the coastal strip is owned by the State Department of Transportation, but the Park manages the area under an agreement with the State (National Park Service 1989). A small wetland or brackish pond is found in this northern stretch of the Park's coastline; this pond is at the mouth of small gulch. Apparently water has been diverted from this gulch and intermittent stream bed upslope of the Park (William Akau and Daniel Kawaiaea, pers. comm. 1996). The coastal trail follows the relatively rocky shoreline to a point below *Mailekini Heiau*, where the trail from the existing Park headquarters and the two *heiau* reaches the coast. The coast trail continues north to the brackish pond and the *Pelekane* area; beyond this area another trail continues through *kiawe* forest to the highway and the John Young Homestead.

Vegetation along the southern part of the coastal trail is predominantly buffelgrass with scattered *kiawe* trees; this area formerly was covered by a coastal *kiawe* forest (Macneil and Hemmes 1977). Since the earlier survey, native coastal plants such as *põhuehue* or beach morning glory (*Ipomoea pes-caprae*) and *pā`ū o Hi`iaka* have colonized the shoreline in the southern part of the Park. Near *Mailekini* and north to the brackish pond, *kiawe* trees are more numerous and larger. The northern shore of the park also has a greater diversity of native and Polynesian species; coconut palm, *milo, hala*, and *naupaka kahakai* grow here along with the alien tree heliotrope (*Tournefortia argentea*) and mixed native and alien low shrubs and herbs. Except for *hala*, these species were present during the earlier survey; the *hala* trees may have been planted subsequent to the 1975-76 survey (Macneil and Hemmes 1977).

A brackish pond or wetland is found near the shore at the mouth of the small gulch (*Pohaukole*) that traverses the Park north of *Pu`ukoholā Heiau*. Vegetation along the edge of the pond is mostly *`aki`aki* grass (*Sporobolus virginicus*) and *`ākulikuli* (*Sesuvium portulacastrum*); prior to an alien plant removal project there was a large infestation of pickleweed here. Milo trees also grow on the edge of the wetland, and one large Canary date palm (*Phoenix canariensis*) has persisted here for more than twenty years (Macneil and Hemmes 1977; Pratt and Abbott 1996c). *Kiawe* trees form a dense forest to the north and east. Herbaceous plants along the trail near the pond are a mix of natives and aliens. Natives include *pā`ū o Hi`iaka*, *`ākulikuli*, and *kīpūkai* (*Heliotropium curassavicum*); *`aweoweo* (*Chenopodium oahuense*) was formerly found here, but was not noted in the most recent survey. Several species of alien saltbush are common near the pond.

Current or past vegetation management at site. - Past management of vegetation included removal of *kiawe* from much of the coastal strip between the southern boundary and the coast below *Mailekini Heiau*. There is an ongoing project to reduce kiawe in the northern part of the Park. The coastal trail is periodically treated with the herbicide Roundup to remove alien grasses and herbs encroaching on the path. This coastal trail management required approximately 7 days in 1996; more time is spent on alien plant treatment during the wetter winter months (Amerling 1996). A recent project was undertaken to eradicate pickleweed at the brackish pond, using the herbicide Rodeo. Approximately 8 days were spent on this project in 1996, which required monthly attention during the winter and spring and only one treatment during the summer months (PUHE files). By the end of 1997 complete control of pickleweed had been achieved, although the area will be monitored, and other aliens may be targeted here (Peter Amerling, pers. comm. 1997).

Vegetation management needed to achieve desired condition. - Treatment of alien plants along the coastal trail will be a continuing management project. While *kiawe* has been greatly reduced from the forest that formerly covered most of the coastal strip, this area will require much more effort before kiawe is eliminated. The Park's goal should be the complete removal of *kiawe* between the southern boundary and the coast near *Mailekini Heiau* to provide an uninterrupted view of *Pu`ukoholā Heiau* from the coastal trail and the proposed new Visitor Center (National Park Service 1989; Harry *et al.* 1996). Some scattered *kiawe* should be removed from the open grassland vegetation *mauka* of the now unused, old road to Spencer Beach. Reduction of *kiawe* is also desirable along the shore near the brackish pond. A few large *kiawe* trees should be left at appropriate spots along the coastal trail to provide shade for visitors, until more suitable native or Polynesian species are planted.

The successful eradication of pickleweed from the small wetland is very promising, but periodic monitoring will be required to prevent its re-invasion. Control of additional alien species near the pond may permit the eventual restoration of native wetland species.

Recommendations:

- Continue periodic treatment of the coastal trail to keep it clear of alien plants.
- Expand *kiawe* removal efforts to include the cutting, treatment, and removal of all trees in the coastal strip between the southern boundary to the coast below *Mailekini Heiau*.

Recommendations (Continued):

- Leave a few tall *kiawe* along the coastal trail to provide shade for visitors, until these shade trees can be replaced with native or Polynesian tree species.
- Monitor the brackish pond for pickleweed and retreat the weed, if necessary.
- Remove the Canary Island date palm on the side of the brackish pond.
- Target puncture vine for removal from the coastal strip, if possible. Attempt saltbush removal to enhance the recovery of native herbaceous species near the brackish pond.

Restoration of native or Polynesian plants. - A number of native strand plants are suitable for restoration or augmentation in the coastal strip below the coastal trail. In a series of recommendations and responses to a Park planting plan, Beatrice Krauss suggested several native and Polynesian species as appropriate for planting near the ocean; these included *hala, hau, naupaka kahakai, pololei* (*Ophioglossum polyphyllum* = *O. concinnum*, *pā`ū o Hi`iaka, milo, kou*, and *niu* or coconut (Krauss 1977, 1978). Except for *hau, kou*, and the fern *pololei*, all the species suggested by Miss Krauss are now present in low numbers in the coastal strip of the Park, and *pololei*, and *kou* trees occur elsewhere in the Park.

A few trees are needed along the coastal trail to provide shade. *Milo* may be a good choice of potential shade tree to plant in a few spots between the proposed new Visitor Center and the trail to *Mailekini* and *Pu`ukoholā Heiau.* Several native species that have been lost from the halophytic community adjacent to the beach and brackish pond (Macneil and Hemmes 1977) should be restored to the Park. Plantings of coconut, *hala, milo*, and *naupaka kahakai* should be used to augment the few individuals already present at the northern section of the Park's coastline; only species appropriate to the supposed historic scene should be used here. *Naupaka* and low-growing native strand plants are appropriate species to plant in the southern part of the Park's coastal strip to increase the native species diversity of the strand and to augment the numbers of the native plants already present.

Recommendations:

- Plant several individuals of *milo* or other native tree species along the coastal trail from the proposed new Visitor Center to the junction of the trail to *Pu`ukoholā Heiau.*
- Restore several native species lost from the coastal strip or the wetland between 1977 and 1993. Species apparently missing from the Park since the earlier survey include *`aweoweo*, *alena* (*Boerhavia repens?*), *nohu* (*Tribulus cistoides*), and *koali `awahia* (*Ipomoea indica*). Macneil and Hemmes (1977) noted two *`aweoweo* plants near the wetland; *koali `awahia* was seen in open scrub; and *alena* and *nohu* were found near the coast. Seeds of *`aweoweo* are available elsewhere in *Kohala* District. If propagation material cannot be found nearby for *alena, nohu,* and *koali `awahia*, Kaloko-Honokōhau NHP is a potential source of seeds of all three of these relatively common species.
- Augment the sparse native vegetation of the southern part of the coastal strip with species found near the brackish pond and *Pelekane*. The shrub *naupaka kahakai* and low-growing natives such as *kīpūkai, pā`ū o Hi`iaka*, and *`ākulikuli* may be especially suitable to this area because they will not interfere with the view from the trail to the *heiau.* Where trees are acceptable along the coastal trail *hala* and *milo* are good choices for planting.
- Experiment with the introduction of *makaloa* sedge (*Cyperus laevigatus*) in the area of the brackish pond where pickleweed and other aliens have been removed.

Trailside Vegetation on Other Park Trails

Description of features and vegetation. - The coastal trail is proposed to be the primary entrance into the Park after the new Visitor Center is constructed near the southern boundary with Spencer Park. In addition to the coastal trail, there are two other trails in use within the Park: a trail from the existing Visitor Center to the coast, passing *Pu`ukoholā* and *Mailekini Heiau;* and a trail leading through *kiawe* forest from the brackish pond and *Pelekane* to the Highway and the John Young Homestead (Fig. 13).

The trail from the existing Visitor Center passes through the planted and landscaped area adjacent to the lawn and irrigated land surrounding the center. Between the developed area near the Visitor Center and *Pu`ukoholā Heiau* the vegetation is an open scrub of scattered *kiawe* in a grassland dominated by buffelgrass. The only two native species seen along the trail are low shrubs of *`uhaloa* and *`ilima*, but a few individuals of several alien annual herbs are seasonally present. Below *Pu`ukohola Heiau*, there is a cleared area with little vegetation; this may have formerly been used for parking vehicles. From *Mailekini Heiau* and the out-of-service paved road, the trail to the coast follows an old dirt road. In addition to buffelgrass, notable trailside species are wild spider flower (*Cleome gynandra*), Australian saltbush, and puncture vine. The Visitor Center trail joins the coastal trail below *Mailekini Heiau.*

Beyond the wetland at the mouth of *Pohaukole* Gulch and past *Pelekane*, the trail turns upslope and leads to the *Waimea-Kawaihae* Highway and the John Young Homestead. The trail from the coast upslope to the John Young Homestead passes through a dense forest of tall *kiawe* trees with mixed alien shrubs and grasses. Macneil and Hemmes (1977) called this vegetation a fluvial closed forest and noted that it occurred along *Makeahua* Gulch and throughout the northern part of the Park. In a recent survey of Park vegetation (Pratt and Abbott 1996c), dense *kiawe* forest was seen from the northern proposed boundary to *Pohaukole* Gulch, essentially the same area described in the earlier survey. The forest understory supported a few alien shrubs and grasses not seen in the southern half of the Park, such as lantana (*Lantana camara*), castor bean (*Ricinus communis*), Sacramento bur (*Triumfetta semitriloba*), and Guinea grass (*Panicum maximum*). The only native plant noted along this trail was *`ilima*, although Macneil and Hemmes (1977) found *nohu* in the fluvial forest more than 20 years ago.

Current or past vegetation management at site. - Both the Visitor Center trail and the trail to the John Young Homestead are periodically treated to prevent the encroachment of alien plants. In 1996, this effort required approximately 12 partial days per year for the trail from the existing visitor center to the coast; treatment of trail vegetation was undertaken every month during the fall and winter, but little trail work was necessary in the spring or summer. No treatment of trail vegetation was carried out on the trail to the John Young Homestead in 1996 (Amerling 1996). The heavily shade along much of the John Young Homestead trail through *kiawe* forest suppresses the growth of many herbaceous alien plants, but periodic trimming of *kiawe* limbs and removal of alien brush is required to keep the trail clear.

Vegetation management needed to achieve desired condition. - Continued periodic treatment of weeds along the two trails is necessary to maintain open conditions. If possible, the Park should attempt to eradicate the noxious puncture vine along the trail near *Mailekini Heiau*, as well as at other sites within the Park. The prickly fruits of this species will prevent visitors from walking barefoot, and the species has the capability of infesting all the trails and much of the Park's coastal strip. *Kiawe* trees encroaching on the *Mailekini* site from below should be removed, but a few shade trees should be allowed to remain until they can be replaced with natives or Polynesian species. Beyond trimming *kiawe* and keeping the trail to the John Young Homestead clear, it is probably not critical to focus on removal of undesirable alien plants in this dense *kiawe* forest on State land. Species such as Sacramento bur, lantana, and Guinea Grass in forest along the trail to the John Young site are too abundant to easily remove. These potentially invasive species should be confined to the *kiawe* forest and not allowed to invade the rest of the Park. Castor bean and *ēkoa* or *koa haole* (*Leucaena leucocephala*) have been suggested as the focus of eradication efforts; both species grow along the trail through the *kiawe* forest, as well as in the *Pohaukole* gulch near its junction with the current *Waimea-Kawaihae* Highway.

Recommendations:

- Continue to periodically treat the main Park trails with the herbicide Roundup to prevent the encroachment of alien plants.
- Eradicate the noxious alien puncture vine from the trail near *Mailekini*, as well as from other Park sites

Recommendations (Continued):

- Prevent *kiawe* trees from encroaching on the trail from the coast to *Mailekini Heiau.*
- Remove one large *kiawe* tree from the side of the trail below *Mailekini* when it can be replaced by a suitable native shade tree (see below).
- Beyond keeping *kiawe* cut back from the trail to the John Young Homestead, do not focus management efforts in the dense *kiawe* forest on State land.
- Confine several alien shrub and grass species (lantana, Sacramento bur, Guinea grass) to the northern *kiawe* forest and prevent them from expanding into the rest of the Park.
- If possible, eradicate castor bean and *ēkoa* from the Park; these two shrub species currently grow in the *kiawe* forest near the trail to the John Young Homestead and in *Pohaukole* Gulch.

Restoration of native or Polynesian plants. - The trail from the current Visitor Center to the coast passes through a currently open area near the two *heiau*, and no outplanting of woody species is desired here, as it is important to preserve the view of *Pu`ukoholā Heiau* from the coast. *Pili* grass restoration to the disturbed area (possibly a former parking area) adjacent to the trail below *Mailekini* is a possible restoration project in this area; introduction of the native grass to this currently bare area will complement the restoration of *pili* to the area between the two large *heiau*. There is one large *kiawe* tree adjacent to the trail below *Mailekini Heiau* that currently provides shade along the path; replacement of this tree with a native is desirable, but such planting should be sited so that the view of the *heiau* from the coastal trail is not blocked. *Milo* or *hala* are possible choices for a replacement shade tree. Future tree planting must be carried out in a way that does not affect any subsurface archaeological resources. No restoration of natives is warranted in dense *kiawe* forest along the trail to John Young Homestead; this area is owned by the State, and large-scale management by the Park Service is impractical.

Recommendations:

- Introduce *pili* grass to the bare area adjacent to the trail below *Mailekini Heiau.*
- Replace an existing large *kiawe* tree on the trail below *Mailekini Heiau* with a suitable native tree to provide shade, such as *milo* or *hala.*
- No native plant outplantings are recommended for the trail through dense *kiawe* forest from the coast to the John Young Homestead.

John Young Homestead

Description of features and vegetation. - The John Young Homestead is one of the features specifically mentioned as deserving of protection in the Park's enabling legislation (National Park Service 1989). John Young was a British sailor who became an influential advisor and chief of *Kamehameha* I and was later Governor of Hawai`i Island. He was given land near *Kawaihae* where he built a complex of structures that incorporated both Western and traditional Hawaiian elements. The site is historically important because of the significance of John Young in the formation of the Hawaiian kingdom under *Kamehameha* and the role he played in the transition of Hawai`i after European contact. The John Young Homestead also includes the first known Western style structures in the Hawaiian Islands (Apple 1978; Rosendahl and Carter 1988). Kirch (1985) considered the John Young Homestead one of the most important archaeological sites of the historic period in Hawai`i and speculated that future studies of the site would add greatly to our knowledge of the critical period of early contact between Hawaiians and Westerners.

There were formerly two parcels of land in the John Young Homestead, an upper portion and a lower portion near the shore. The upper part of John Young Homestead is protected within the boundaries of the Pu`ukoholā Heiau NHS (Fig. 13), but the lower portion of the homestead is apparently now buried beneath the coral fill of the *Kawaihae* Harbor project (Greene 1993). The upper part of the John Young Homestead is located directly upslope of the *Waimea-Kawaihae* Highway between *Makahuna* and *Makeāhua* Gulches. Archaeological work conducted in 1978 on the ridge between the two gulches identified the remains of eight

features within the complex (Rosendahl and Carter 1988) (Fig. 14). Five of the features were constructed in the Hawaiian style and included two potential house platforms, a paved terrace, a mound possibly used as an earth oven, and a burial platform. The Western-style structures were stone-walled enclosures with mortar and plaster associated with John Young's residence. Buildings of the complex were begun in 1793; the Western house was built in 1798; and additional construction or improvements continued throughout the first two decades of the 19th century (Greene 1993). One of the Western structures (designated structure 2) was excavated and stabilized by backfilling in 1978, and the walls of another (Western structure 1) were stabilized and protected with a roofed shed in a previous project carried out by Edmund Ladd (Rosendahl and Carter 1988). Unfortunately, bulldozer tracks now scar the site of the Homestead (Fig. 14).

The current vegetation of the John Young Homestead is predominantly alien in origin. The area in the immediate vicinity of the recognized features of the site has been cleared and is sparsely vegetated with buffelgrass, the indigenous *`uhaloa*, and a mixture of herbaceous aliens, such as wild spider flower, nettle-leaved goosefoot (*Chenopodium murale*), stinkgrass (*Eragrostis cilianensis*), and the noxious puncture vine. *Kiawe*, the dominant tree of the Park overall, is conspicuous on the sides of the adjacent gulches and between the site and the highway.

Current or past vegetation management at site. - Alien vegetation consisting of "brush and thick grass" were removed from the site during the last archaeological excavation twenty years ago (Rosendahl and Carter 1988). As *kiawe* trees have not significantly reinvaded the cleared site in the interim, this woody species has obviously been periodically removed in the last twenty years. The current vegetation management of the site involves the periodic spraying of mixed alien species with the herbicide Roundup. This project required portions of 5 days during 1996, concentrated in the winter and fall months (Amerling 1996).

Vegetation management needed to achieve desired condition. - The desired condition of the vegetation of the John Young Homestead is a recreation of the historic scene of the 1790s and early 1800s. Travelers to *Kawaihae* in the early 1800s, including a few who visited John Young's house, described a barren landscape, but at least one visitor (Otto von Kotzebue in 1816) reported coconut and banana trees (*Musa* sp.) associated with the house (Greene 1993). Photographs taken in 1882 that may represent the John Young house site are reproduced in Greene (1993); they depict a nearly treeless landscape with a few distant coconut and *kiawe* trees near the shore. In the photographs, only tufts of grass and unidentifiable low shrubs are seen growing in the rocky ground upon which the remains of John Young's house stand, although the extremely bare condition of the vegetation may be due to use of the area for grazing cattle or goats.

The most appropriate vegetation management at present may be the continued suppression of *kiawe* in the surrounding area and the periodic treatment of alien plants in the ground cover at the site of the John Young Homestead. The *kiawe* trees between the *Waimea-Kawaihae* Highway and the site are providing a screen from the view and noise of the highway and also partially block the view of the *Kawaihae* Harbor development. These should be left in place as long as the current highway is in use. When the new road is aligned on the *mauka* boundary of the Park (National Park Service 1989), some of the *kiawe* may be cut to restore a more open appearance to the area between the John Young Homestead and *Pu`ukoholā Heiau*, but it may be desirable to leave in place those *kiawe* partially blocking the *Kawaihae* view. A vegetative screen to block the view of the new highway alignment will be desirable in the future, and native or Polynesian tree species should be used for this purpose. If the disturbed quarry near the Highway south of the John Young Homestead is eventually chosen as the site to construct a maintenance building and storage yard, as was proposed in the recent Park DCP (National Park Service 1989), a screen of vegetation will be needed to hide the view of new structures from the Homestead site.

Recommendations:

- Continue to treat encroaching alien plants near the remains of the known Western-style and Hawaiian structures at the John Young Homestead.
- Prevent *kiawe* from increasing beyond the strip along the Highway and the edge of the gulches.
- Leave tall *kiawe* along the *Waimea-Kawaihae* Highway in place until the road is realigned. After road realignment, *kiawe* clearing may be desirable between the John Young Homestead and *Pu`ukoholā Heiau*, but trees should be left in place that screen the view of *Kawaihae* Harbor.
- Leave *kiawe* in place along the edge of the gulch south of the John Young Homestead to provide a vegetative screen that hides or softens the view of the proposed maintenance buildings and storage yard in the old quarry.
- Eradicate the noxious puncture vine from the John Young Homestead as part of a program to remove the alien plant from the Park.

Restoration of native or Polynesian plants. - As most descriptions of the John Young Homestead from the early 1800s depict a treeless, bare area, there is little historical justification for planting woody species at the site. Possible exceptions are native and Polynesian tree species to be used as a visual barrier to screen the site from modern developments. Banana and coconut palms, mentioned by one early visitor as surrounding the house, might possibly be planted at the site, but they will probably not survive without irrigation.

Krauss (1977) suggested the reintroduction of Hawaiian and historical food plants to the John Young Homestead site after setting up an irrigation system; *`uala* or sweet potato and *uhi* or yam (*Dioscorea alata*) were her suggestions for most likely crop plants in the area. In later correspondence with Park rangers, Miss Krauss named other Hawaiian and historical food plants as potential plantings at the site, including *kalo* or dry *taro* (*Colocasia esculenta*), *kō*, *ipu*, *hala*, *mai`a* or banana (*Musa paradisea*), onions (*Allium cepa*), pumpkins (*Cucurbita pepo*), squash (*Cucurbita* sp.), and several native medicinal plants, such as *`uhaloa*, *`ilima*, and *ko`oko`olau* (*Bidens* sp.) (Krauss 1978; PUHE files).

Ships traveling by *Kawaihae* in the late 1700s and early 1800s were supplied with plant foods by Hawaiians, who presumably grew them nearby. Menzies, who was with Vancouver in 1793, noted "the appearance of industrious cultivation" on many small fields in the vicinity of *Kawaihae* Bay (Menzies 1920). Some of the fruits and vegetables mentioned in the journals of ship captains and early visitors are watermelons (*Citrullus lanatus*), cantaloupe (*Cucumis melo*), cucumbers (*C. sativus*), tomatoes (*Solanum lycopersicon*), cabbages (*Brassica oleracea*), sugar cane, *taro*, and sweet potatoes (Clarke 1983; Greene 1993). While John Young was apparently cultivating crops on his lands near *Kawaihae* (Greene 1993), no mention of such crop plants (other than banana) was made by early 19th century visitors to the site, and no agricultural remains have been identified in site excavations (Rosendahl and Carter 1988). Therefore, the large-scale introduction of Hawaiian and early Western crop plants to the immediate vicinity of the John Young Homestead does not seem to be warranted by the available historical information. However, if an area near the Homestead ruins could be examined archaeologically and found to be acceptable for modification and irrigation, demonstration plantings of *`uala, uhi, kalo*, and medicinal plants would certainly add to the interpretation of the John Young Homestead. Two of the native plants with medicinal uses suggested by Miss Krauss, *`uhaloa* and *`ilima*, already occur within the Park and should be added to the John Young Homestead site.

Recommendations:

- After archaeological clearance of an area near the John Young Homestead, select an area for demonstration plantings of Hawaiian and early historical crop plants.
- Begin outplanting of food and medicinal plants with hardy species likely to persist under dry conditions, such as *`uala* and *uhi*. Expand to additional species only if irrigation is possible.

Recommendations (continued):

- After the *Waimea-Kawaihae* Highway is realigned along the *mauka* boundary of the Park, outplant suitable native or Polynesian species along the Park's boundary with the road to act as a screen. If water is available for such an outplanting, suggested species are coconut palm, *hala, milo*, and *hau.*
- If maintenance buildings are constructed in the old quarry south of the John Young Homestead, plant suitable native and Polynesian tree species along the edge of the gulch south of the house site to screen the view of the modern developments in the quarry.

Existing Visitor Center and Parking Area

Description of features and vegetation. - The existing Visitor Center houses the administration offices and visitor contact station in a building built as a temporary structure in the 1970s. The complex also includes a small maintenance and storage building, tanks, portable restrooms, and a parking lot (Fig. 13). Adjacent to the Visitor Center is a lawn and irrigated area around which approximately 20 native and Polynesian plant species, as well as more than 10 alien species, have been planted. Plantings also separate the existing parking area from the lawn and visitor center complex. Some of the alien plants growing here are volunteers among the plantings. The Development Concept Plan (DCP) for the Park (National Park Service 1989) calls for the eventual removal of the buildings and parking lot when the new visitor center is constructed near the coast on the southern boundary of the Park.

Vegetation in the area surrounding the Visitor Center is predominantly open buffelgrass with scattered *kiawe* trees and assorted low-growing alien herbs and shrubs. There is one patch of *pili* growing mixed with buffelgrass approximately 30 m (100 ft) from the Visitor Center parking lot; this native grass was only recently noted at this Park site (Curt Daehler, pers. comm. 1998). The lawn adjacent to the visitor center was created after the Park became operational in 1974-75. The lawn is composed primarily of Bermuda grass and carpet grass (*Axonopus* sp.), but also contains at least nine other small alien grass species and approximately ten alien herb species. While all the herbaceous plants in the lawn are alien species, none represents a threat to existing vegetation. *Hala* trees are prominent in the planted area between the visitor center and the parking lot. More than 10 Polynesian introductions have been planted near the Visitor Center as examples of plants Hawaiians used as food, fiber, or medicine. Native trees that have been planted in the area include *koa* (*Acacia koa*), *wiliwili, milo*, and *loulu.* Native shrubs planted on the edge of the lawn and irrigated site are *naupaka kahakai* and *`a`ali`i.* Some of these native and Polynesian species were suggested for outplanting by ethnobotanist Beatrice Krauss in a restoration report and subsequent letters (Krauss 1977, 1978), following the original botanical survey of the Park (Macneil and Hemmes 1977).

Current or past vegetation management at site. - Sometime after the construction of the temporary visitor center and administration offices, a lawn was created and several *kiawe* trees and a Chinese banyan tree were retained to provide shade to visitors. Plantings of native, Polynesian and a few alien species were concentrated near the visitor center and parking lot, and on the edge of the lawn. An irrigation system was put in place to enhance the survival of plantings. Current management of the Visitor Center grounds includes mowing and the periodic herbicide treatment of mixed weed species. Alien plant control at the Visitor Center grounds, planted area, and parking lot required approximately 9 days in 1996; this area was sprayed with Roundup for weeds roughly every other month (Amerling 1996). At this site and other areas managed within the Park, the treatment schedule is dependent on rainfall. Greater effort is required to treat weeds following wet months (Peter Amerling, pers. comm. 1997). In addition to alien plant control, vegetation management near the Visitor Center includes mowing and care of plantings.

Vegetation management needed to achieve desired condition. - This priority site has perhaps the most complex set of vegetation management problems within the Park. Because a great deal of work has gone into the development of the area surrounding the temporary Visitor Center, abandonment of the plantings here will result in a loss of native plants and may be viewed by some as a step backwards. However, it is

impossible to encourage the growth of tall vegetation at the site and protect the integrity of the extremely important viewshed of *Pu`ukoholā Heiau.* Possible management strategies are:

(1) Leave plantings and irrigation in place until the new Visitor Center is built and then remove all plantings and take out the lawn when the temporary buildings and parking lot are removed. The advantage to this strategy is protection of the viewshed of *Pu`ukoholā Heiau* from disruption by growing trees that may obscure the horizon upslope of the *heiau.* The disadvantage to this strategy is that many native and Polynesian plant species appropriate to the Park would be removed and the benefits of past planting efforts would be lost. Also, removal of the existing lawn will result in the loss of a pleasant place for groups to congregate.

(2) Leave the lawn and all plantings in place and use the area for group activities even after the headquarters is moved. The advantages of this strategy are the retention of a number of native and Polynesian plant species and the possibility of continued use of the lawn for group activities. The disadvantages of this strategy are that it does not protect the viewshed of *Pu`ukoholā Heiau* from encroachment of tree plantings, and several inappropriate alien outplantings are retained, some of which may eventually spread to other sites in the Park.

(3) When the new Visitor Center is constructed, remove inappropriate plantings and tall plants that may interfere with the view of *Pu`ukoholā Heiau* from viewing sites at the new Visitor Center and coastal trail, move those native plants that are amenable to transplanting (perhaps the *loulu* palms), leave low-growing shrubs appropriate to the area in place, and leave the lawn for potential use of group activities. This compromise strategy has the advantage of protecting the view of *Pu`ukoholā Heiau* by removing tall plants, retaining native and Polynesian shrub species appropriate to the Park, and at least temporary retention of the lawn until other sites can be developed for group use.

Recommendations:

- Implement Strategy 3 and develop a plan for removing inappropriate plantings, retaining low-growing native and Polynesian plants that will not disrupt the view of *Pu`ukoholā Heiau*, and moving some native species to the new Visitor Center or coastal sites near *Pelekane.*
- Suggestions for species to remove from the current Visitor Center and parking lot (and to eliminate from the Park) are African tulip tree (*Spathodea campanulata*), citrus tree (*Citrus* sp.), papaya (*Carica papaya*), pineapple (*Ananas comosus*), money tree (*Pleomele marginata*), monkeypod tree (*Samanea saman*), and autograph tree (*Clusia rosea*). The large Chinese banyan tree that formerly grew in the lawn near the Visitor Center has already been removed.
- Outplanted species that should be retained, if they are demonstrated not to interfere with the viewshed of *Pu`ukoholā Heiau*, are *naupaka kahakai, `a`ali`i, `ākia* (*Wikstroemia* sp.), *noni* (*Morinda citrifolia*), *ma`o* or Hawaiian cotton (*Gossypium tomentosum*), *ma`o hau hele* (*Hibiscus brackenridgei*), and *wiliwili.*
- Native plants and Polynesian introductions that could perhaps be moved from the current Visitor Center to the proposed new Visitor Center or other suitable sites are *loulu* palms, *hala, kou, wauke, kī, kamani* (*Calophyllum inophyllum*), banana (*Musa x paradisiaca*), *`ōlena* (*Curcuma longa*), and *pia* (*Tacca leontopetaloides*).

Restoration of native or Polynesian plants. - No additional plants should be outplanted in the area near the current Park Visitor Center, although the area may be used temporarily to propagate native plants for placement elsewhere within the Park.

Proposed New Visitor Center and Parking Area

Description of features and vegetation. - The recent Development Concept Plan (DCP) for Pu`ukoholā Heiau NHS proposed three alternative sites for the development of a permanent visitor center and

parking area to replace the existing "temporary" structure (National Park Service 1989). Two potential sites were proposed on the southern boundary of the Park near the coast adjacent to Spencer Beach Park, and a third potential headquarters site on State land to the north of the Park's proposed boundary was rejected as unfeasible because of land ownership. The site selected as the preferred area for the new Park headquarters is the upper site on the Park's southern boundary just east of the old road to Spencer Beach Park (Fig. 15). A survey of this preferred site indicated that no archaeological or cultural features will be destroyed by development at this relatively flat site, and the advantages of the area are an excellent view of the two *heiau* that are the primary resources of the Park, proximity to the new access road from the highway to Spencer Beach Park, and a position slightly removed from the parking lot and current development at the adjacent beach park. Proposed developments here include administrative offices, a visitor orientation area, exhibits, and a parking lot. A short spur road will connect the parking lot to the new access road from the highway to Spencer Beach Park, and a short trail will be developed to connect to the current coastal trail. This trail will eventually become the primary access to the rest of the Park (National Park Service 1989).

The current vegetation of the site proposed for the new Visitor Center is dominated by buffelgrass and scattered *kiawe* trees with a few additional scattered alien herbs and low shrubs. The only native plants known from this area are the common shrubs *`ilima* and *`uhaloa*.

Current or past vegetation management at site. - No vegetation management has been specifically directed at this site, but the nearby coastal strip has been the focus of *kiawe* removal efforts in the last two decades. The nearby access road to Spencer Beach Park is currently sprayed with herbicide to kill alien plants on the side fronting the Park. This management requires an effort of 1-2 partial days, roughly every quarter (Amerling 1996).

Vegetation management needed to achieve desired condition. - After the new Visitor Center and parking area are developed, the site will require periodic maintenance to prevent encroachment of alien plants, particularly along the edge of the new parking lot and roadsides of the short connecting road from the center to the new Park access road. The level of management will vary with the amount of area landscaped or planted with native and Polynesian plants. The Development Concept Plan (National Park Service 1989) presents a proposal for a relatively small administration building and an open-air visitor orientation area. Native and Polynesian plants used in landscaping the Visitor Center will enhance its appearance and provide material for education and interpretation (See next section). Care should be taken during construction to avoid the introduction of new alien plant species on heavy equipment or other vehicles. As suggested by the DCP, the continued removal of encroaching *kiawe* trees along the coastal trail and between the new Visitor Center and *Pu`ukoholā Heiau* will enhance the visual impact of the *heiau*. A screen of trees may be desired to block the view of Spencer Beach Park from the new Visitor Center; it may be appropriate to leave in place any *kiawe* trees directly on the Park boundary between the proposed Visitor Center and the beach park, at least until native and Polynesian replacements are ready for outplanting as vista screens.

Recommendations:

- Avoid the introduction of new alien plants during the construction phase of the proposed new Visitor Center. Monitor disturbed areas and treat newly establishing alien plants as needed.
- Develop a management schedule for treatment of mixed alien plants in disturbed areas adjacent to the new Visitor Center and parking lot.
- Continue to cut and remove *kiawe* trees encroaching on the previously cleared coastal strip near the new Visitor Center and between the center and *Pu`ukoholā* and *Mailekini Heiau*.
- Leave in place those *kiawe* trees that provide screening between the new Visitor Center site and Spencer Beach Park.

Restoration of native or Polynesian plants. - Several native and Polynesian trees and shrubs already present in the Park or appropriate to such a dry lowland site may have potential as ornamental plantings

around the Visitor Center and parking lot. The Park DCP (National Park Service 1989) suggested the use of *milo*, *hau*, and *hala*, as well as the Polynesian coconut palm, to provide shade and screening at the new Visitor Center. Coconut palms may not be appropriate to the site, because they will eventually exceed the roofline of the proposed Visitor Center (Laura Schuster, pers. comm. 1998). *Milo* and *hala* are already growing along the coast of the Park to the north, and they have been planted near the temporary Visitor Center and will likely be successfully introduced to the new site. To this list of suggested shade and landscaping trees at the new center could be added *kou*, a Polynesian species with showy orange flowers, and *wiliwili*, an endemic species native to the dry lowlands elsewhere on the island. Both species currently grow as plantings in the vicinity of the old Visitor Center. The native coastal shrub *naupaka kahakai*, which is often used in landscaping in *Kailua-Kona* and is easy to propagate (Bornhorst 1996), is another suggested planting for the new Visitor Center (National Park Service 1989). This shrub occurs naturally along the coast north of the new visitor center site and also has been planted at the old Visitor Center. *`Ilima*, already present at the site, and *`a`ali`i*, currently planted elsewhere in the Park, may have landscaping value near the new Visitor Center.

If herbaceous or ground cover plants are needed for landscaping, the Park already contains several attractive native vines or herbs. Three coastal vines that may have landscaping potential are *pōhuehue*, a hardy species with large trumpet-shaped pink flowers; *pā`ū o Hi`iaka*, a slender vine with delicate white or violet flowers; and *`ākulikuli*, a succulent plant with fleshy red-tinged stems and tubular pink flowers. The indigenous *kīpūkai*, a succulent herb with blue-tinged foliage and tiny white flowers, may also have value as an ornamental ground cover; this species currently grows in the Park near *Pelekane.*

Recommendations:

- Develop a landscape plan for the site (that will also function as a site management plan), utilizing species from the lists above. Tree species with potential for landscaping are coconut, *milo, hala, hau, kou*, and *wiliwili.* Shrub species with landscaping uses are *naupaka kahakai*, *`a`ali`i*, and *`ilima.* Herbaceous species that may be of value as plantings are *pōhuehue, pā`ū o Hi`iaka, `ākulikuli*, and *kīpūkai.*
- Landscape the new Visitor Center and perimeter of the parking area with native species and Polynesian introductions already found in the Park or appropriate to the site. Some species, such as coconut palm and *naupaka kahakai*, may be commercially available. Others will have to be propagated from seeds available within the Park or at nearby coastal sites in *Kohala* and North *Kona.* Amy Greenwell Ethnobotanical Garden may be able to assist with plant propagation.

Old Spencer Beach Park Road between Pu`ukoholā and Mailekini Heiau

Description of features and vegetation. - A paved two-lane road accessing Spencer Beach Park and *Pu`ukoholā* from the State Highway was already in place when the Park was established. This road, separating *Pu`ukoholā* from *Mailekini Heiau*, was in use until the New Spencer Beach Park access road was constructed in 1995-96 (Fig. 13). The presence of the paved road so close to the most significant sites in the Park was visually intrusive, and vibrations from vehicle traffic on the road were thought to be potentially damaging to the *heiau*. The recent Development Concept Plan for the Park called for the eventual removal of the pavement and restoration of the site (National Park Service 1989).

The current vegetation along the decommissioned road is primarily buffelgrass with very scattered *kiawe*. *Kiawe* is more common along the upslope portion of the old road near its junction with the Highway. Macneil and Hemmes (1977) found 12 species along the roadside in their survey more than twenty years ago. In addition to buffelgrass and two other alien grasses, they noted the alien succulent blue-seeded portulaca (*Portulaca pilosa*), three annual herbaceous aliens, *kiawe, ēkoa*, hairy abutilon, and two native shrub species (*`uhaloa* and *`ilima*). Except for the three annual herbs and *ēkoa*, the same species were present along the old road in a survey carried out in 1992-94, and a few additional alien herbaceous species were noted, including an unidentifiable grass and the red-flowered herb *Boerhavia coccinea* (Pratt and Abbott 1996c).

Current or past vegetation management at site. - There is no current management of vegetation along the old road from the Highway to Spencer Beach Park (Amerling 1997). The area just *makai* of the old road was part of the coastal strip in which *kiawe* has been thinned over the last 20 years. As *ēkoa* has been recognized as an alien plant to be eradicated (National Park Service 1996d), and it was not seen along the old road in the most recent survey, the shrub may have been removed from the roadside area in the recent past.

Vegetation management needed to achieve desired condition. - After removal of the old asphalt paving, the road corridor may require some input of soil to permit plant growth. Any addition of soil or other substrate should be done with sterilized material to prevent the introduction of additional non-native plants. If outplantings or seed sowing of native and Polynesian plants are not done after road material removal, the site will certainly be invaded by grasses and herbs already present within the Park, particularly buffelgrass.

Recommendations:

- After asphalt removal, prepare the site to support native plants.
- Take care not to introduce new alien plant species with unsterilized soil or soil amendments. Another source of alien seed introduction is equipment from other areas.
- Outplant or sow native and Polynesian species appropriate to the area (see next section).

Restoration of native or Polynesian plants. - A recent vegetation management proposal suggested replanting the old road bed with *pili* and seeds of *`uhaloa* (*hi`aloa*), *`ilima*, *pā`ū o Hi`iaka*, and *`a`ali`i* (Laughlin 1991). These species, with one exception, are excellent choices of low-growing, drought-tolerant native plants likely to survive in this dry area. All are currently found within the Park. While an appropriate species to plant at other Park sites, *`a`ali`i* may not be a good choice for planting along the old road because it is capable of growing into a large shrub or small tree. It is important to plant only species that will not interfere with the view of *Pu`ukoholā Heiau* from the coastal trail or impact the prominence of the *heiau* by their presence upslope (Harry *et al.* 1996). Seeds of *`uhaloa, `ilima*, and *pā`ū o Hi`iaka* are available within the Park, but seeds for *pili* sowing and propagation may have to be obtained outside the Park, because only a few plants still occur at sites near *Pu`ukoholā Heiau* and the current Visitor Center. *Pili* is perhaps the best choice for a native species that has the capability to grow in large, relatively dense stands to cover the disturbed area of the removed road surface. It will be most esthetically pleasing if *pili* plants are also outplanted in an irregular pattern in areas adjacent to the roadbed, so that the end result does not look like an artificial swath of grass.

Recommendations:

- Collect seeds of *`uhaloa*, *`ilima*, and *pā`ū o Hi`iaka* inside the Park and collect *pili* seeds inside and outside the Park. While there are a few stands of *pili* along the coastal road north of *Kawaihae,* seeds may have to be collected from farther away. Kaloko-Honokōhau and Pu`uhonua o Hōnaunau NHP have small stands of *pili,* and Hawaii Volcanoes NP has relatively large expanses of the grass. Even though it is preferable to use a local seed source when revegetating a site, this is perhaps a lesser consideration with a widespread indigenous (or Polynesian) species such as *pili.*
- Propagate native plants within the Park or at another lowland site. Amy Greenwell Ethnobotanical Garden may be able to participate in a propagation program.
- Try both seed sowing and outplanting of propagated individual of *pili* and other native species along the roadbed to be revegetated.
- Hand water newly outplanted natives and weed out encroaching alien species until the plantings are well established.

Park Boundaries and Lands near Kawaihae Harbor and Spencer Beach Park

Description of features and vegetation. - Pu`ukoholā Heiau NHS is a small park of less than 24 ha (60 a), and it is already impacted by development on both north and south boundaries that potentially detract from the historic scene most suitable for appreciation of the Park's historical and cultural resources. The *Kawaihae* Harbor development in 1959 greatly altered the shoreline of *Kawaihae* Bay and created an expanse of coral fill, artificial structures, and a breakwater visible from sections of the Park. The southern boundary of the Park directly abuts Spencer Beach Park, with its parking lot, ornamental plantings, picnic facilities, building, and restrooms (Fig. 15). Showy non-native trees and shrubs planted at the Spencer Beach parking lot directly adjacent to Pu`ukoholā Heiau NHS include monkeypod, royal poinciana (*Delonix regia*), plumeria (*Plumeria* sp.), and bougainvillea (*Bougainvillea* sp.). Upslope of Spencer Beach, the land is currently undeveloped, but may eventually support a golf course and resort or housing developments (National Park Service 1989). The highway connecting *Kawaihae* to *Waimea* and the Queen *Ka`ahumanu* Highway is a visually obtrusive element separating the John Young Homestead from the rest of the Park, but a proposed new alignment of the road will place it east of the Park's current boundary (National Park Service 1989). The area upslope of the Park's eastern boundary is currently undeveloped.

Vegetation along the Park boundaries is varied. Along the road to Spencer Beach Park and the southern boundary of the Park, vegetation is a very open buffelgrass community with scattered *kiawe* trees, *ēkoa* shrubs, low-growing native *`uhaloa* and *`ilima*, and a few additional alien herbs and grasses scattered throughout the grassland. Near the Spencer Beach parking lot, at least one dense clump of *kiawe* trees helps to obscure the County Park developments from view. The northern boundary of the Park with the *Kawaihae* Harbor complex is covered by a dense *kiawe* forest with a sparse understory of alien shrubs and grasses. The eastern boundary of the Park adjacent to grazing land upslope is vegetated with buffelgrass, *kiawe*, and assorted alien shrubs and herbs.

Current or past vegetation management at site. - Currently alien plants are treated with herbicide along the verge of the road to Spencer Beach Park. This alien plant control effort required approximately 5 days in 1996, concentrated during the winter months and at three month intervals in the summer and fall (Amerling 1996). Reduction of *kiawe* in the area adjacent to the State land of the *Kawaihae* Harbor complex has been a Park goal to reduce the hazard of fire. Several prescribed burns have been conducted in this area to reduce fuel and help reduce the density of *kiawe* trees (Jack Minassian, pers. comm 1997). No current vegetation management is underway on the eastern boundary of the Park upslope of the existing *Waimea-Kawaihae* Highway.

Vegetation management needed to achieve desired condition. - The periodic treatment of alien plant species along the roadside to Spencer Beach Park should be continued, but outplantings of native shrub species should be investigated as a means to improve the appearance of the roadside Park boundary and reduce the amount of time required for periodic retreatment of the area with herbicide. Continued reduction of *kiawe* near the northern Park boundary is desired to reduce fire hazard and restore historical scene. Some *kiawe* should be left in place on State's land managed by the Park, to act as a screen to block development at the Harbor. Eventually, it is desirable to plant appropriate native and Polynesian species to replace *kiawe*; possible species suitable for a vista screen near the northern border with *Kawaihae* are *milo, hala, kou, noni*, and coconut palms.

Recommendations:

- Continue to treat the verge of the road to Spencer Beach Park, but initiate native shrub outplantings (see below) here to shade out alien herbs and grasses and eventually reduce the time required to treat this area with herbicide.

Recommendations(continued):

□ Continue the reduction of dense *kiawe* near the northern boundary of the Park with the *Kawaihae* Complex, but leave at least a band of *kiawe* trees as a screen between the Park and the Harbor with its associated development.

□ There is currently no need for vegetation management along the eastern Park boundary with pasture lands upslope.

Restoration of native or Polynesian plants. - Roadside plantings of low-growing native species are desirable along the road to Spencer Beach Park that will eventually provide access to the proposed new Visitor Center. Vegetation may be used as a screen to block the view of the parking lot, buildings, and alien ornamentals planted at Spencer Beach Park. Clumps of *kiawe* trees are currently serving this function, but native tree species could also be used to provide this desirable screening. Vegetation is needed as a visual barrier on the northern boundary of the Park with *Kawaihae* Harbor lands.

Recommendations:

□ Propagate *naupaka kahakai* for outplanting along the roadside to Spencer Beach Park. These native shrubs will be far more attractive than the current assortment of alien grasses and shrubs in this area, and once they are established the herbicidal control of alien plants along the roadside will be far less time consuming and possibly unnecessary.

□ Plant native and Polynesian tree and shrub species such as *milo, hala, kou*, and *noni* where needed to provide vegetation along the Park's southern boundary to screen the view of development at Spencer Beach Park.

□ Plant native and Polynesian tree and shrub species such as *milo, hala, kou*, coconut, and *noni* where needed to provide a vegetation screen near the Park's northern boundary that will reduce the view of development at the *Kawaihae* Harbor Complex from the primary sites of Park visitation.

Alien Plant Management at Other Sites

While vegetation management at most of the Park's priority sites involves the treatment of suites of alien species to be removed as a group, several alien plant species may be individual targets for eradication from Pu`ukoholā Heiau NHS. Alien plants that require management throughout the Park or in specific areas not included in the above list of priority sites are discussed below.

Puncture Vine (*Tribulus terrestris*)

Puncture vine is a prostrate, annual herb with hairy, pinnately compound leaves and small yellow flowers. Its dry fruits are sharply spiny, a feature that makes this alien species very undesirable in a Park where visitors are likely to walk barefoot or with minimal footwear. The species is native to the Mediterranean region of Europe and has been in the Hawaiian Islands for about 50 years, where it is common on sandy soil in disturbed areas (Wagner *et al.* 1990). It is widely naturalized and recognized as a pest in the mainland United States (Lorenzi and Jeffery 1987). Puncture vine was formerly listed as a noxious weed by the State Department of Agriculture (Haselwood and Motter 1966). In the last survey of Pu`ukoholā Heiau NHS, puncture vine was found occasionally along trails near *Mailekini Heiau* and at the John Young Homestead (Pratt and Abbott 1996c). The weed is also present at a cultural demonstration area near *Pu`ukoholā Heiau*. This is one of the species targeted for control in the Park's current Integrated Pest Management (IPM) plan (Amerling 1997). Currently infestations of puncture vine are treated with a dilute mixture of either Roundup or Rodeo in water. Despite periodic spraying, it has not been possible to easily eradicate this species.

Recommendations are to decrease the interval between treatments and to spray the plants before the height of the fruiting season. Monthly monitoring will be required to determine the best times to spray this species; this should be done when flowers are abundant, but fruits have not yet appeared or ripened. For this

weed, some authors recommend the use of pre-emergent herbicides that provide residual control along roadsides and waste places (Lorenzi and Jeffery 1987); it would be logical to test an herbicide such as Oust (sulfometuron methyl) for use against puncture vine in the Park. While mechanical removal of puncture vine by hoe cutting has been used effectively in the past (Pope 1968), the species is currently too widespread in the Park for this control method. Precautions should be taken in the future to avoid dispersal and reintroduction of this pest species in fill or other material. Contaminated fill material may be the original mode of dispersal of puncture vine into the Park (Amerling 1997).

Castor Bean (*Ricinis communis*)

Castor bean is a shrub or small tree native to Africa, but it is now widely distributed in the world because of the commercial value of its oil. The species was an early introduction to Hawai`i and is now naturalized at low elevations on all the main Hawaiian Islands (Wagner *et al.* 1990). Forms of castor bean with colored foliage have reportedly been used as ornamentals in Hawai`i (Pope 1968). Because of its rapid growth and poisonous properties, castor bean is often considered a pest. Castor bean is uncommon at Pu`ukoholā Heiau NHS, where it grows primarily in dry gulches and beneath *kiawe* trees along the trail from the John Young Homestead to the coast (Pratt and Abbott 1996c). This is one of the alien species considered potentially noxious in the first botanical survey of the Park (Macneil and Hemmes 1977). Current management of this species in the Park involves the periodic spraying of Roundup and Rodeo along trailsides and on the *heiau*. The species has been targeted for eventual eradication, but has been found to be resistant to glyphosate (Amerling 1997).

Recommendations are to test other herbicides for use against this species in the Park. Hawaii Volcanoes NP has successfully used both Garlon 4 and Banvel on castor bean. Banvel is applied to cut stumps of large plants (100%, undiluted), and Garlon 4 is used as a foliar spray on seedlings and young plants (1% in water) (Tunison and Zimmer 1992; Chris Zimmer, pers. comm. 1998). The current treatment method at Pu`ukoholā Heiau NHS seems to be relatively effective along trailsides and at archaeological sites, so it may be possible to eradicate the species from the Park if all stands are found, mapped, and treated at an appropriate interval of several months.

Chinese Banyan (*Ficus microcarpa*)

Chinese or Malayan banyan is a tree capable of reaching large size; it often starts development as an epiphyte on other trees. Its small, orange figs are produced in abundance by large trees, and birds act as dispersal agents for the tiny seeds. The species was introduced as an ornamental plant and as a potential reforestation tree (Hartt 1980); unlike most banyan species in Hawai`i, this one has become naturalized because the necessary pollinating wasp species was also introduced to Hawai`i (Wagner *et al.* 1990). While this banyan is not always considered a pest, its habit of rooting among the rocks of walls makes it potentially damaging to archaeological features. During a recent survey of plants at Pu`ukoholā Heiau NHS, Chinese banyan was noted as one large tree in the lawn adjacent to the existing visitor center and as scattered young trees along the edge of a nearby gulch (Pratt and Abbott 1996c). As the species was not found in the previous botanical survey of the Park (Macneil and Hemmes 1977), banyan appears to be a recent introduction to the area. Amerling (1997) speculated that the species was dispersed to the Park by birds. While this is entirely possible, the positioning of the one large tree adjacent to the Visitor Center implies that it was intentionally planted; this large tree was recently cut and removed from the Park. Chinese banyan is mentioned in the Park's IPM plan as a species to be removed; the proposed method is treatment of cut stumps with 100% Garlon 3A or 25% Roundup (Amerling 1997).

It is recommended that the scattered young trees along *Pohaukole* Gulch be cut and treated with herbicide as specified in the Park IPM plan. To facilitate eradication of the species from the Park, it is recommended that a map be made of all current localities and that a post-treatment monitoring scheme be

developed to ensure a complete kill of individual plants. Periodic monitoring of likely reinvasion sites will have to be carried out at intervals of perhaps five years to prevent the recolonization of the Park by bird-borne seeds of banyan. If the proposed herbicides and treatment are ineffective, it will be prudent to try another method of application recently tested on Chinese banyan by Motooka (1995); this is the application of either glyphosate (Roundup) or triclopyr (Redeem/Remedy) to drilled holes in the banyan trunk. The reported injury rating to banyan five months after treatment was 90%.

Fountain grass (*Pennisetum setaceum*)

Fountain grass, a large bunchgrass native to northern Africa, is one of the worst alien plant pests in the Hawaiian Islands (Smith 1985). Because of its arching filiform leaves and fluffy, pink inflorescences, fountain grass has been considered valuable as an ornamental. (This grass species continues to be sold as an ornamental and promoted by gardening magazines.) It was introduced to Hawai`i and escaped cultivation in the early 1900s. The grass has become an aggressive invader of dry open areas in Hawai`i, and it promotes destructive fires in invaded dry forests (Wagner *et al.* 1990). While it is common at Pu`ukoholā Heiau NHS, fountain grass is far less abundant than is buffelgrass. Fountain grass is currently concentrated along roadsides (particularly the verge of the *Waimea-Kawaihae* Highway) and in gulches (Pratt and Abbott 1996c; Amerling 1997). Twenty years ago, fountain grass was rated as common in the scrub grassland community, but the species was found along roadsides at only one point near the *Waimea-Kawaihae* Highway (Macneil and Hemmes 1977). The grass has been recognized as a fire hazard at Pu`ukoholā Heiau NHS. Fountain grass was removed by mechanical means (hand-pulling) at some sites in the Park in 1996. While the species is designated in the Park IPM plan as a priority for eradication from the Park, any potential eradication project will likely be time-consuming and costly (Amerling 1997). The grass may be killed with a foliar application of a dilute solution of Roundup or Rodeo, when leaves are green and actively growing. Amerling (1997) estimated that 1,500 fountain grass plants were present in stream beds in the Park.

Several other parks or natural areas on Hawai`i Island have fountain grass eradication or control programs. Hawaii Volcanoes NP has created a buffer zone to restrict the grass to its coastal lowlands, where it is manually uprooted (Tunison 1992) or treated with the pre-emergent herbicide Velpar (hexazinone) in a foliar spray of 10% Velpar in water (Chris Zimmer, pers. comm. 1998; Tunison *et al.* 1994). At *Pōhakuloa* Training Area, herbicide trials indicated that hexazinone in conjunction with manual control was highly effective against fountain grass, and glyphosate (Roundup) was also found to be an effective herbicide (Castillo 1997).

While Velpar cannot be recommended for use at Pu`ukoholā Heiau NHS, the relative accessibility of the fountain grass infestation will permit the effective use of Roundup, and in some areas manual removal by uprooting will be possible. At Hawaii Volcanoes NP, localized roadside infestations of fountain grass are treated with a foliar application of 1-2% Roundup in water when the grass is actively growing (Chris Zimmer, pers. comm 1998). Mapping fountain grass occurrences in Pu`ukoholā Heiau NHS will likely make an eradication program more successful. As with other pest species to be eradicated, periodic monitoring of roadsides and probable reinfestation sites will be necessary to prevent the grass from re-invading the Park.

Guinea Grass (*Panicum maximum*)

Guinea grass is a large perennial bunchgrass with wide leaves and a large, open pyramidal inflorescence. Native to Africa, Guinea grass was introduced to Hawai`i more than 100 years ago as a forage grass (Wagner *et al.* 1990). The species is still used as cattle forage in dry pasturelands of *Ka`ū* and *Kona*, and is both palatable and drought-resistant (Whitney *et al.* 1964). Because of its usefulness to ranchers, Guinea grass is not usually thought of as a pest, but its rank growth, large size, and ability to form dense ground cover beneath *kiawe* trees makes it an alien species of concern at Pu`ukoholā Heiau NHS. In the most recent survey of the Park, Guinea grass was found only in dry streambeds and in *kiawe* forest bordering the trail between the John Young Homestead and the coast (Pratt and Abbott 1996c). The species has

persisted in this area for more than 20 years (Macneil and Hemmes 1977). Guinea grass is not mentioned in the most recent IPM plan for the Park (Amerling 1997), but the species should be considered for eradication from the Park.

Removal of the grass now, if feasible, may prevent it from becoming a fire hazard and invader of archaeological sites in the future. It is recommended that informal herbicide trials be carried out in the Park to test a dilute solution of Roundup against the large grass. Pu`uhonua o Hōnaunau NHP has this grass as a dominant ground cover in some areas, and staff workers there may be able to advise on effective control methods.

Ēkoa (*Leucaena leucocephala*)

Ēkoa or *koa haole* is a small tree or shrub with bipinnately compound leaves, globose clusters of white flowers, and long, narrow pods that dry to a dark brown and are persistent on the branches. Native to tropical America, *ēkoa* is widely cultivated as a source of fodder, firewood and shade and has become naturalized in many tropical lands. It was introduced to Hawai`i in 1837 and now grows at low elevation on all the main Hawaiian Islands (Wagner *et al.* 1990). While the shrub is useful as forage for cattle in low-elevation pastures, the tendency to form dense thickets makes *ēkoa* a pest in many areas (Pope 1968). The shrub is not very common at Pu`ukoholā Heiau NHS, where it is found beneath *kiawe* in forests of the northern part of the Park and along the dry streambeds or gulches (Pratt and Abbott 1996c). *Ēkoa* was considered infrequent in the 1977 survey of the Park, but was singled out as a candidate for removal because of the threat of invasion and disturbance of Park archaeological features (Macneil and Hemmes 1977). *Ēkoa* removal was identified as a high priority in the Park's IPM plan. The proposed methods of treatment are either 100% Garlon 3A applied to cut stumps of *ēkoa* or a cut-stump application of a 25% solution of Roundup may be used in some areas (Amerling 1997).

It is recommended that one of the proposed herbicide treatments be carried out wherever *ēkoa* is found in the Park. Records of numbers of plants treated and effectiveness of the treatment will be useful to determine future strategies for this invasive species. If 100% Garlon 3A is not effective, other treatments and herbicides will have to be tested for use on *ēkoa* at Pu`ukoholā Helau NHS.

Past control efforts on *ēkoa* in Hawaii Volcanoes NP (HAVO) used Tordon 10K pellets or a foliar application of 5% Roundup, but neither method was effective. Subsequently HAVO used Garlon 4, 5% in diesel, as a basal bark treatment for *ēkoa*, but this was also relatively ineffective. Several herbicide tests were carried out on *ēkoa* in the 1980s. A test of four different concentrations of Garlon 4 in diesel (0.5%. 2.0%, 5.0%, and 10%) applied to the basal bark of *ēkoa* indicated that all treatments caused defoliation, but resprouts appeared in most plots after 11 months (Kageler 1983). Eldredge and Gardner (1984) tested seven concentrations of Garlon 4 in water on cut stumps of the shrub at Pu`uhonua o Hōnaunau NHP. Early results indicated that only the 10% solution of herbicide showed promise. Gardner (1985) reported on tests carried out in *Mānoa* Valley and a nearby dry ridge. After six months, the most promising cut-stump treatments were 4% Garlon 4 in diesel, 25% Roundup in diesel, 5% Garlon 4 in water, 20% Garlon 4 in water, undiluted Brush-B-Gon (Garlon 3A premixed at 8%), and undiluted Roundup. Basal bark treatments were less successful, particularly at the wet site, but at the dry site Garlon 4 at 4% in diesel, as well as 25% Roundup in diesel, prevented resprouting for the first six months. Motooka (1988) found that Picloram (Tordon) was effective when applied to a notch on *ēkoa*; later, Motooka (1995) found that Tebuthiuron (Spike) pellets at 20 lb/acre gave complete control of the shrub. Tordon may no longer be used in the Park, and soil treatments are probably not desirable on rocky substrates so close to the ocean shore.

Other Localized Alien Plant Species

Other alien plant species should be removed from the Park when they first appear, if they are likely to spread and become more common in the Park. Such an strategy of removal of localized alien plant species

has been used very successfully in Hawaii Volcanoes National Park, where approximately 40 localized alien plant species have been targeted for eradication (Tunison and Zimmer 1992). While control of localized alien plant species is a logical approach that often saves time and money and prevents establishment and spread of new weeds in the Park, some caution must be used in the selection of localized aliens to target, so that time is not spent in the control of innocuous species unlikely to become pests.

Several tree species formerly planted or growing as volunteers near the existing Visitor Center should be removed. African tulip tree, despite its ornamental status and showy orange flowers, should be destroyed before its wind-borne seeds spread to other parts of the Park. A dilute solution of Garlon 3A (50% in water) or Garlon 4 (2% in diesel) applied to the cut stump of the tree will likely kill it (Steve Anderson, pers. comm. 1998; Motooka 1992). Papaya trees should also be removed, as this crop plant is of a much later period than that designated for the historical scene of the Park; there is a slim chance that this species may persist. Autograph tree is growing among plantings near the Visitor Center parking lot and has the capability of growing on rock walls; thus it is a potential threat to the Park's archaeological features. It should be removed immediately. Other inappropriate plantings near the Visitor Center are discussed in the previous section on priority sites for management.

Monitoring and Research Needs

Pololei Fern Monitoring

One site in the Park has consistently supported a population of *pololei*, a relatively rare native fern (Fig. 13). This species was formerly a candidate for listing as endangered, but is no longer being considered for endangered status. A recent checklist of Hawaiian ferns recognized *Ophioglossum concinnum* as a synonym for a species found more commonly outside of Hawai`i (*O. polyphyllum*) (Wagner and Wagner 1995). Nonetheless, this ephemeral fern remains rare in the Park and elsewhere on the island of Hawai`i, and it is reasonable to continue a low level of monitoring to follow the fate of the species within Pu`ukoholā Heiau NHS. Some previous monitoring work has been carried out within the Park. It is recommended that data from past monitoring be analyzed and summarized to help guide future management. Continued monitoring of the fern may include periodic (seasonal) counts of individuals or measurement of area covered by the fern and an assessment of the number of fertile plants. The fern is most likely to be seen during spring months following rainfall events. Such monitoring, carried out over the space of several years, will be very helpful to Park managers.

Buffelgrass Reduction Research and Pili Restoration

Buffelgrass is the most abundant grass and the dominant ground cover of open scrub vegetation in the Park, but it is an undesirable species because of its alien status and the potential fire hazard it represents. The current treatment for the grass is a foliar spray of Roundup or Rodeo when new leaves are actively growing (Amerling 1997). While this method is effective, it is not suitable for use over the entire Park. Even though it is not currently feasible to attack this alien grass Park-wide, it may be possible to test removal methods and replacement with the native *pili* grass on a small scale. A prescribed fire was conducted in buffelgrass in the mid 1980s, but the results are not known. One buffelgrass research project has recently been undertaken within the Park by Dr. Curtis Daehler and graduate students of the Botany Department, University of Hawai`i at *Mānoa*. In this research project, two buffelgrass-dominated sites within the Park will be burned, and subplots will have different combinations of treatments, such as the addition of *pili* seeds, application of herbicide, or watering. A second prescribed fire will be carried out once *pili* grass is established (Daehler 1997). At the recently-discovered *pili* grass patch near the Visitor Center, experimental manual or chemical removal of buffelgrass will test the ability of *pili* to recover after alien plant removal. This naturally-occurring pili may be used as a seed source for later restoration projects in the Park. While the *pili* grass project is still in an early phase, much has been learned about pili dormancy and germination. Young *pili* plants appear to be very sensitive to transplantation (Curtis Daehler, pers. comm 1998).

The final results of this study will provide managers with information to help guide management of this common grass. If an effective control method is found, buffelgrass can be removed from demonstration areas that are visible to visitors, such as the area between *Pu`ukoholā* and *Mailekini Heiau.* After buffelgrass removal, the area can be sowed or outplanted with the native *pili.* Other suitable sites for *pili* restoration are *Pelekane*, the site of the proposed new Visitor Center, and the route of the old road between *Pu`ukoholā* and *Mailekini Heiau* after the pavement is removed. This type of small-scale project will represent a restoration of the cultural scene appropriate to the 1790s and will enhance the ability of the staff to clear the most important archaeological resources of the Park and interpret a culturally useful native plant. If the demonstration project is successful, restoration may be expanded to other high-priority sites in the Park.

Alien Plant Control Methods Research

Most of the alien plants currently being controlled in the Park have known effective treatments, and the same is true for most of the additional alien species proposed for control in the recent Integrated Pest Management (IPM) plan (Amerling 1997). However, a few of the priority weeds within the Park (Table 3) have proven to be recalcitrant, and additional research may be required to find effective herbicidal control methods. Small-scale herbicide research is needed on *ēkoa* to ensure that time is not wasted using ineffective herbicides in the effort to eradicate this shrub from the Park. This species has proven to be very difficult to control at other natural areas within the State. A brief summary of various herbicide treatments that have been tried on *ēkoa* is given in the previous section (as well as in the Pu`uhonua o Hōnaunau NHP section on alien plant control methods research). Testing of cut-stump or basal bark methods of herbicide application should be carried out in the Park to determine the most effective treatment for *ēkoa.* Puncture vine has also been difficult to eliminate from the Park. This noxious, spiny plant should continue to be a high priority for eradication, and small-scale herbicide tests should be initiated to find an effective chemical control method. Pre-emergent herbicides (for example, Oust) should be tested, as they are likely to give longer term control and address the alien plant seed bank problem.

Table 3. Invasive Alien Plant Species of Pu`ukoholā Heiau National Historic Site

Scientific name	Common name	Current Abundance
Batis maritima	Pickleweed	Localized on stream/pond*
Cenchrus ciliaris	Buffelgrass	Abundant
Clusia rosea	Autograph tree	Rare near Visitor Center
Ficus microcarpa	Chinese banyan	Rare in gulch; removed from near Visitor Center
Leucaena leucocephala	*Ēkoa, koa haole*	Uncommon
Pennisetum clandestinum	Fountain grass	Common on roadsides
Ricinus communis	Castor bean	Uncommon in dry streambed
Tribulus terrestris	Puncture vine	Occasional on trails
Triumfetta semitriloba	Sacramento bur	Uncommon along one trail

* Probably eliminated from Pu`ukoholā Heiau NHS in 1996-1997.

Herbicide or control method testing is probably not necessary for several additional alien plant species mentioned in the IPM plan. Wild spider flower, an early introduction from America, has been noted as an invasive species at Pu`ukoholā Heiau NHS (Amerling 1997). While other authors also consider this to be an undesirable plant to exterminate if possible (Pope 1968), the annual life form of this herb, coupled with its tendency to grow primarily on roadsides and other disturbed areas (Wagner *et al.* 1990), reduce its importance as a high priority for control in the Park. There is no reason to believe that spider flower will not respond to treatment with the herbicide Roundup, and it should be one of the suite of alien plants treated at archaeological features and other high priority sites in the Park. Another alien plant pest discussed in the IPM

plan that will likely require very little effort to remove is autograph tree. In the most recent botanical survey of the Park, only one young autograph tree was noted near the Visitor Center parking lot (Pratt and Abbott 1996c). This one individual will probably be killed by the cut stump application of 50% Garlon 3A in water. If it is still relatively small, the plant may be uprooted and removed from the Park.

Monitoring and accurate mapping may be the key to the successful eradication of some alien species from the Park. The experience of resource managers at Hawaii Volcanoes NP may be instructive on the issue of monitoring. For many weed species in their control program, effective control or elimination was not possible until mapping projects had demonstrated the true extent and severity of the infestation. When such information became available to managers, they were able to make more informed decisions regarding feasibility and prioritization of alien plant projects, and were consequently able to develop more effective weed control strategies (Tunison 1992).

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Anderson, Stephen. Resources Management Specialist, Haleakalā National Park, Maui.

Bell, Geraldine. Superintendent, Pu`uhonua o Hōnaunau National Historical Park.

Bio, Victor. Maintenance and Resources Management Worker, Pu`uhonua o Hōnaunau National Historical Park.

Bruegmann, Marie. Botanist, U. S. Fish and Wildlife Service, Pacific Islands Ecoregion, Honolulu.

Daehler, Curtis. Professor, Department of Botany, University of Hawai`i at Mānoa, Honolulu.

Drigot, Diane. Environmetnal Protection Specialist, Environmental Affairs Division, Marine Corps Base, Kaneohe, Hawai`i.

Fronda, Rizal. Maintenance Worker, Kaloko-Honokōhau National Historical Park.

Hommon, Robert. Archaeologist, National Park Service, Pacific Islands Support Office, Honolulu.

Joyce, Gordon. Chief of Protection, Interpretation, and Resources Management, Pu`uhonua o Hōnaunau National Historical Park.

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Figures

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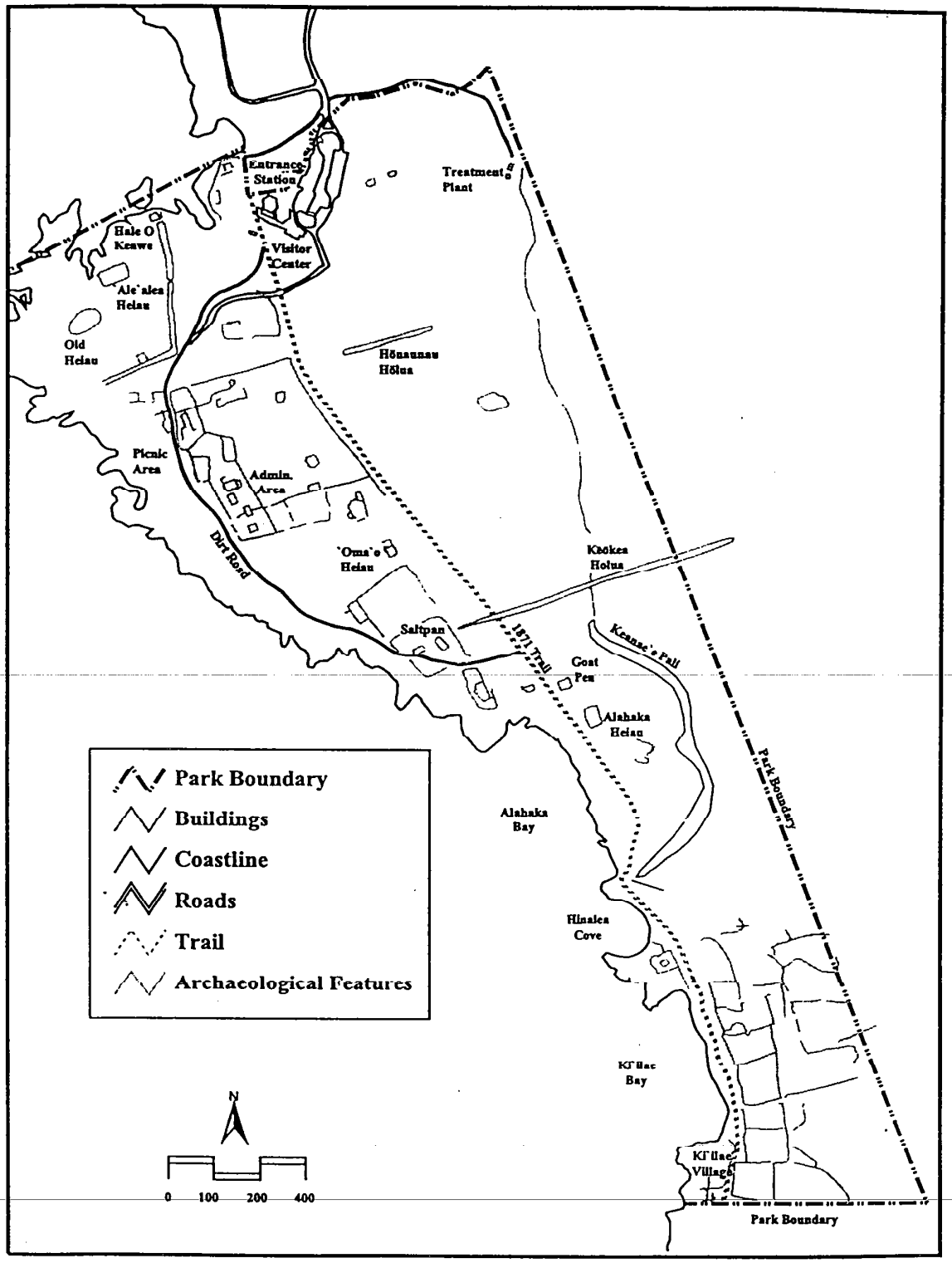

Figure 1. Pu`uhonua O Hōnaunau National Historical Park; showing priority sites for management.

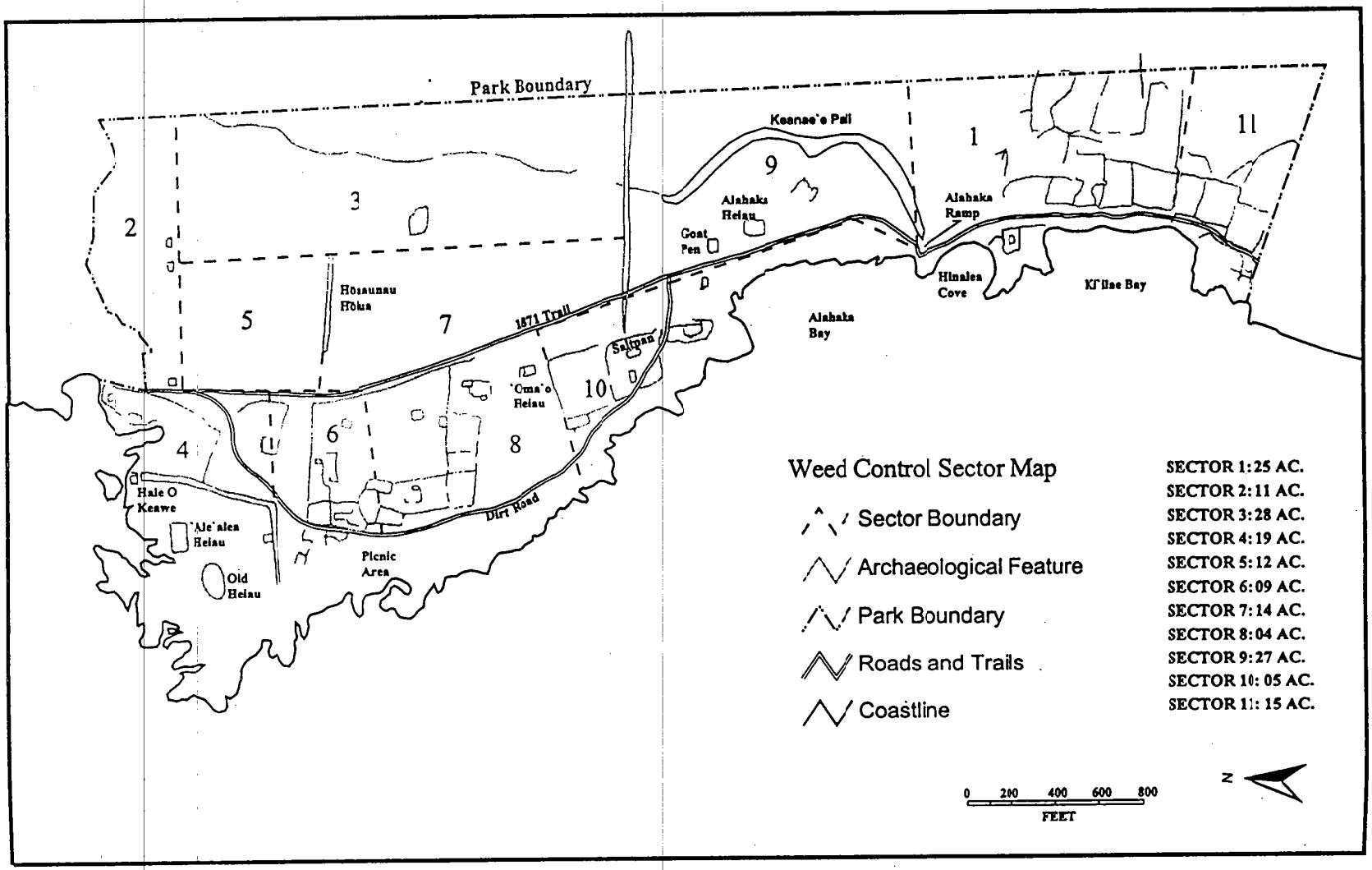

Figure 2. Weed control sector map of Pu`uhonua O Hōnaunau National Historical Park, Hawai`i.

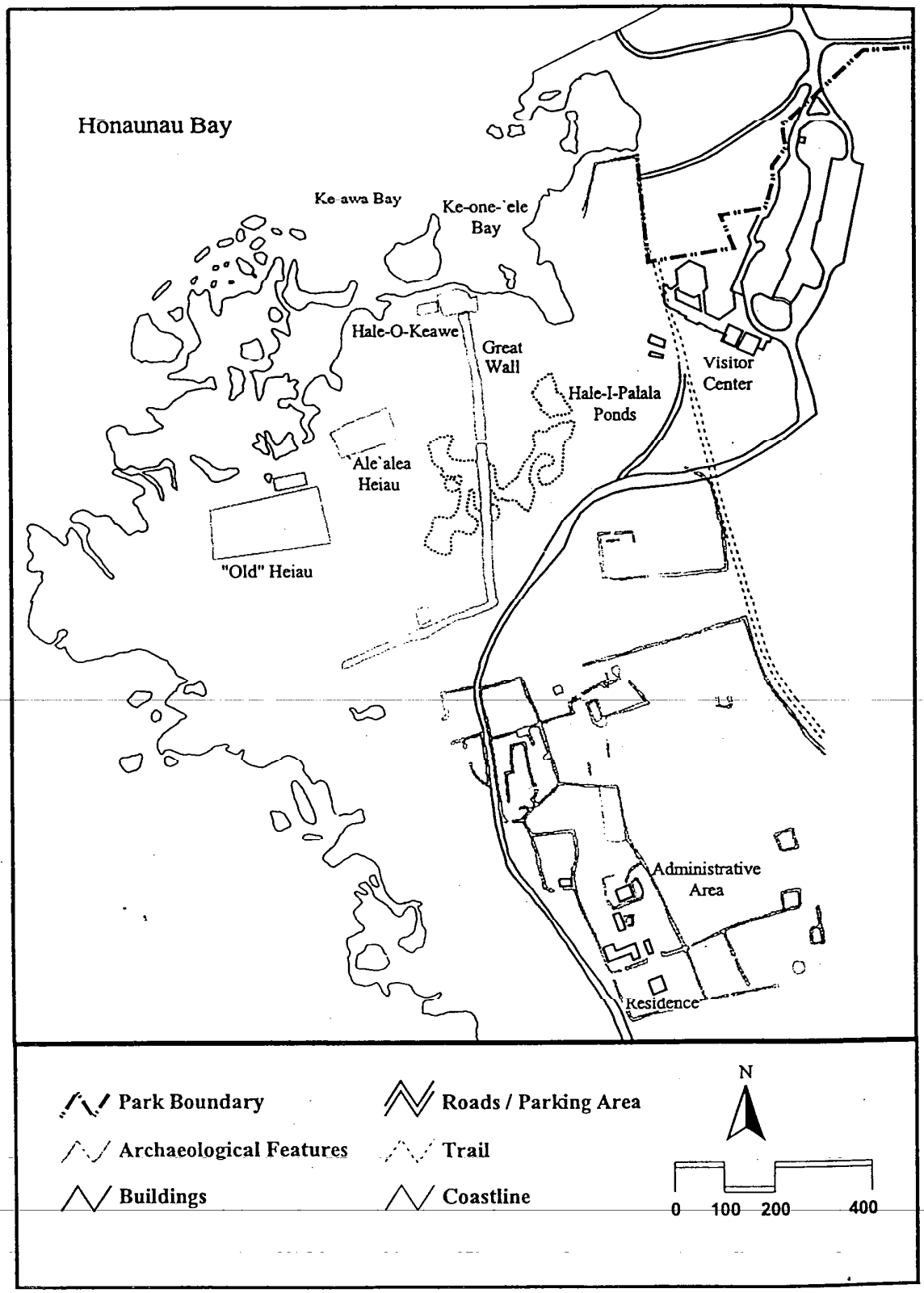

Figure 3. Pu`uhonua O Hōnaunau, the Visitor Center, and the current site of administrative offices in Pu`uhonua O Hōnaunau National Historical Park, Hawai`i.

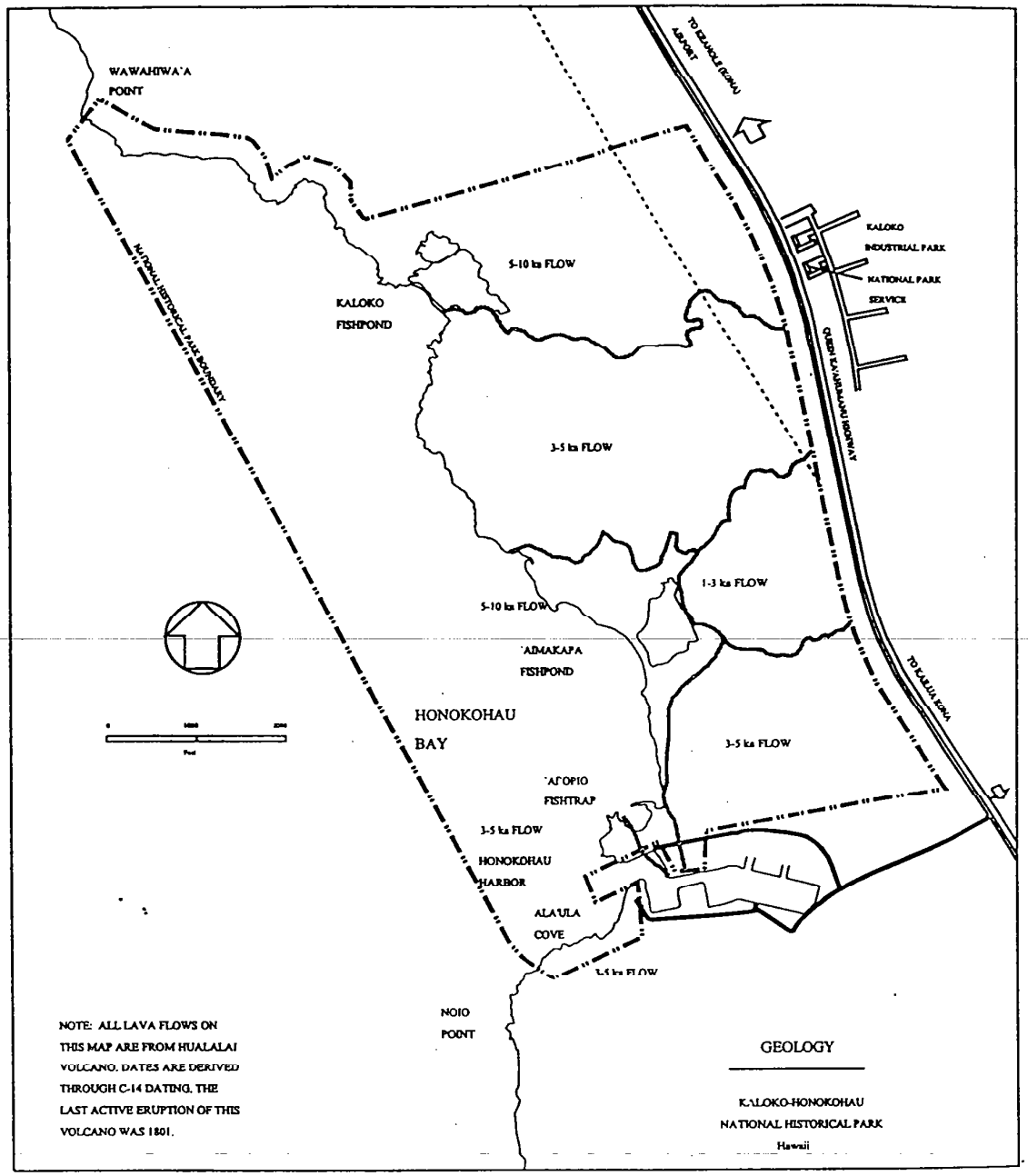

Figure 4. Ages of lava flows within Kaloko-Honokōhau National Historical Park, Hawai'i.

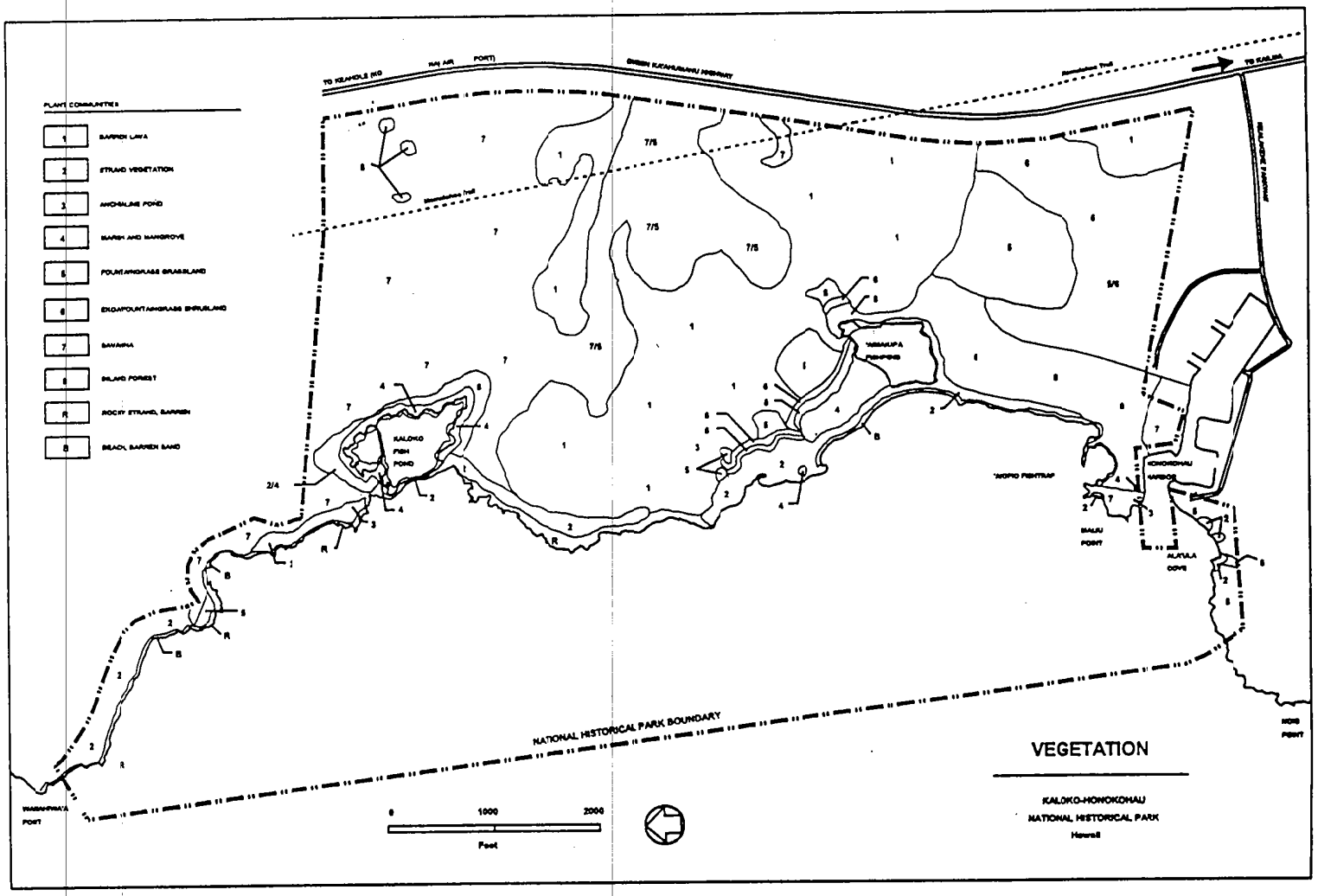

Figure 5. Vegetation map of Kaloko-Honokōhau National Historical Park, Hawai'i (from Canfield 1990).

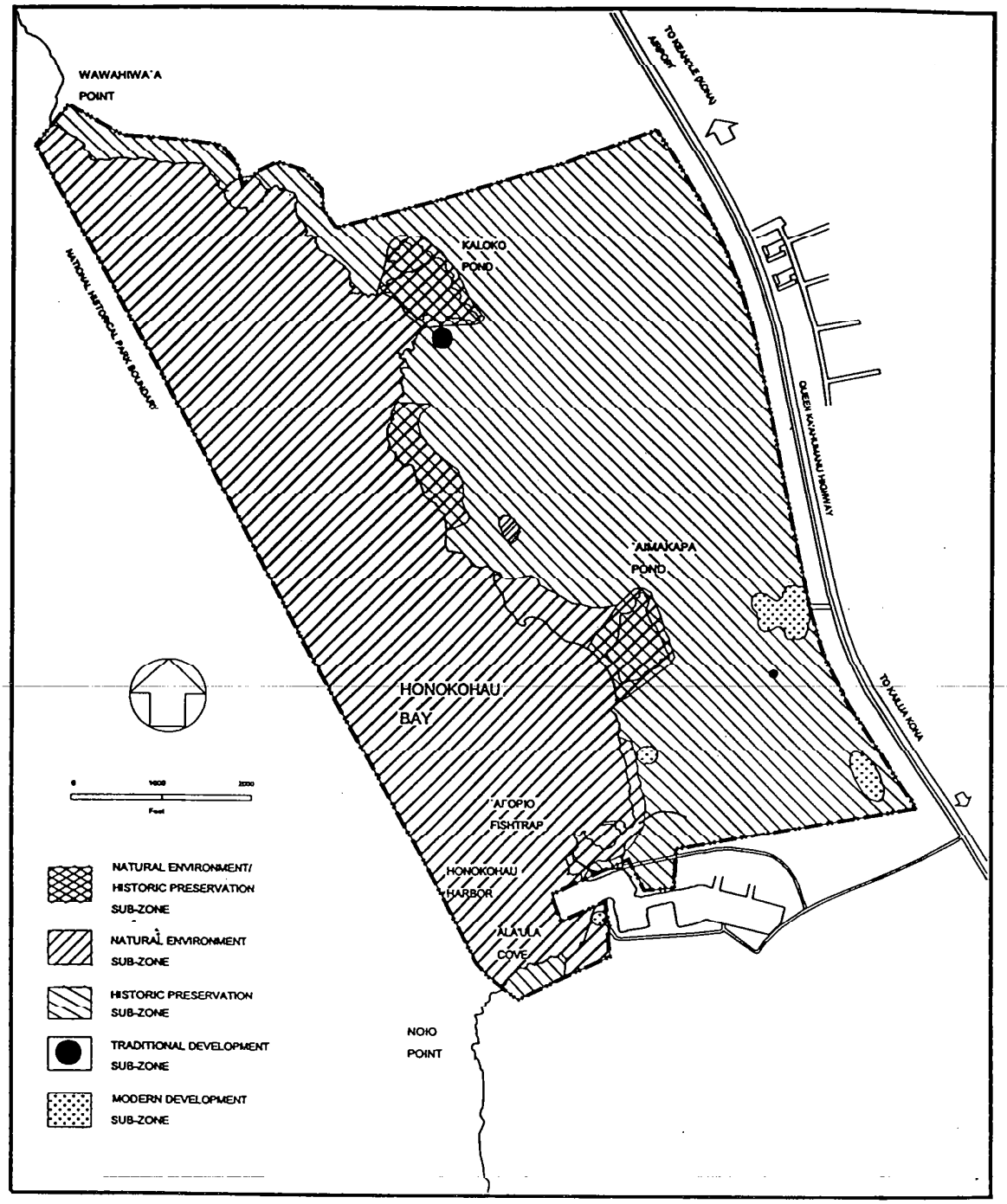

Figure 6. Proposed management zoning for Kaloko-Honokōhau National Historical Park, Hawai`i (from Park GMP, 1994).

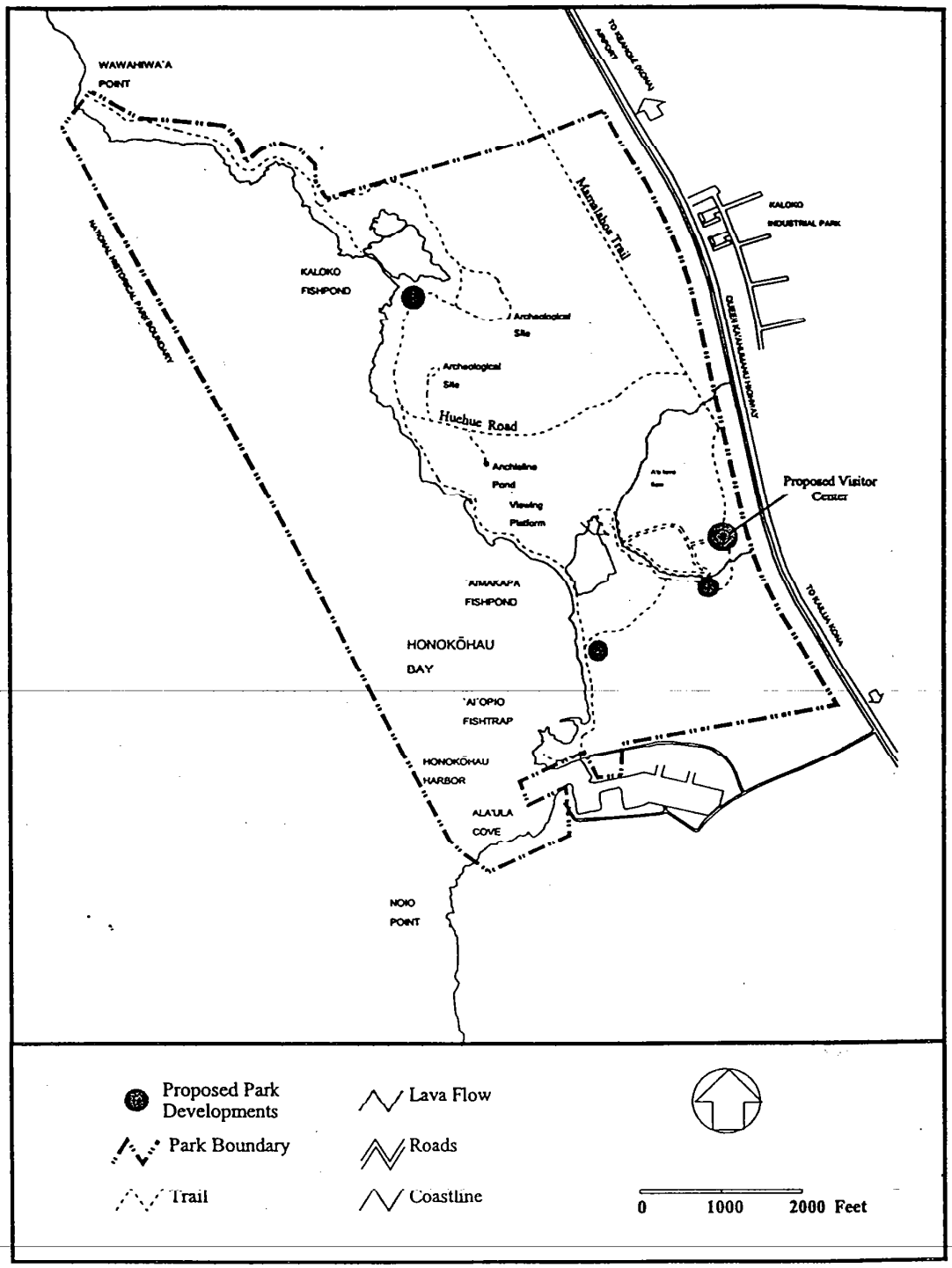

Figure 7. Proposed trail system within Kaloko-Honokōhau National Historical Park, Hawai'i (from Park GMP, 1994).

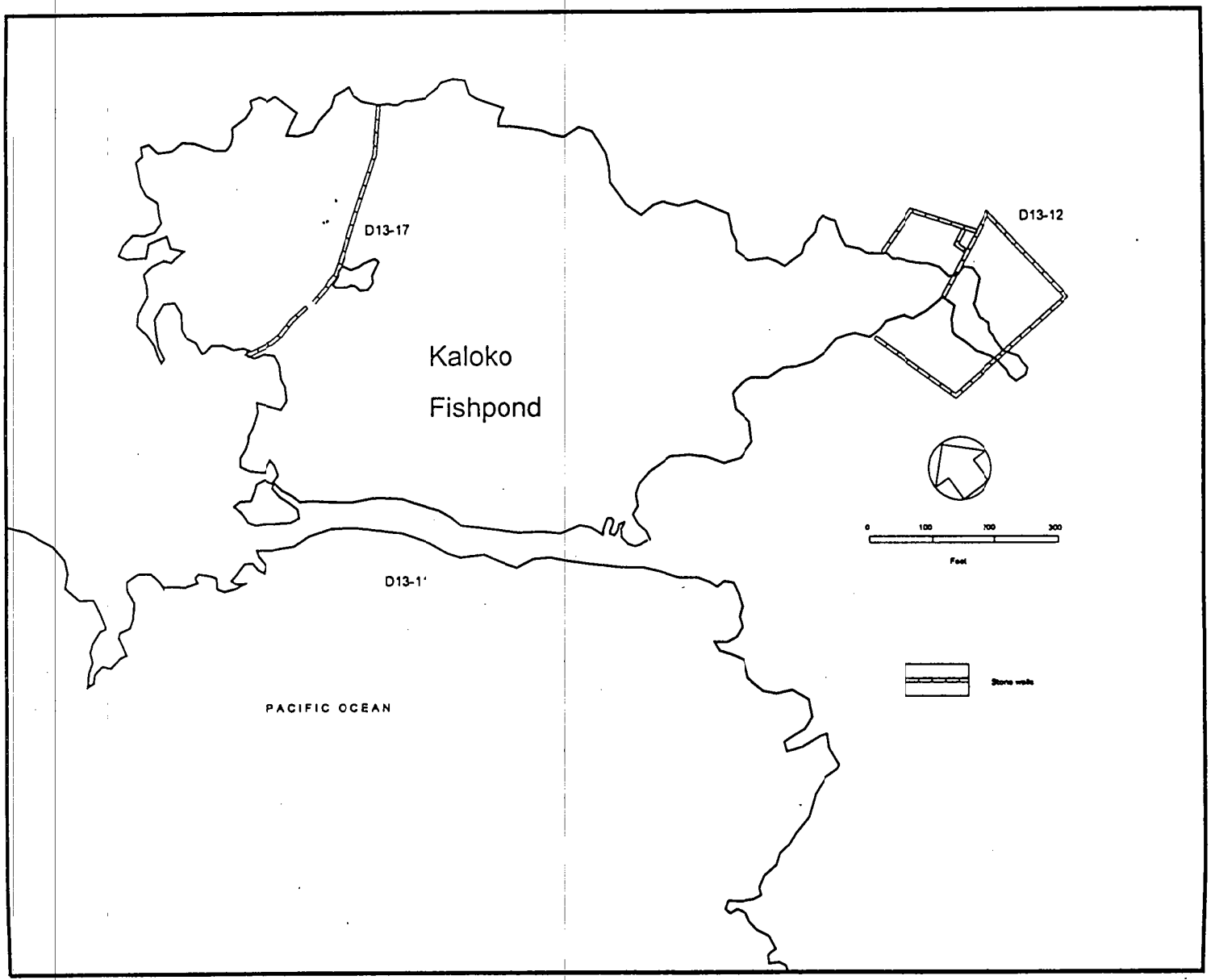

Figure 8. Kaloko Fishpond and associated cultural features, Kaloko-Honokōhau National Historical Park, Hawai'i.

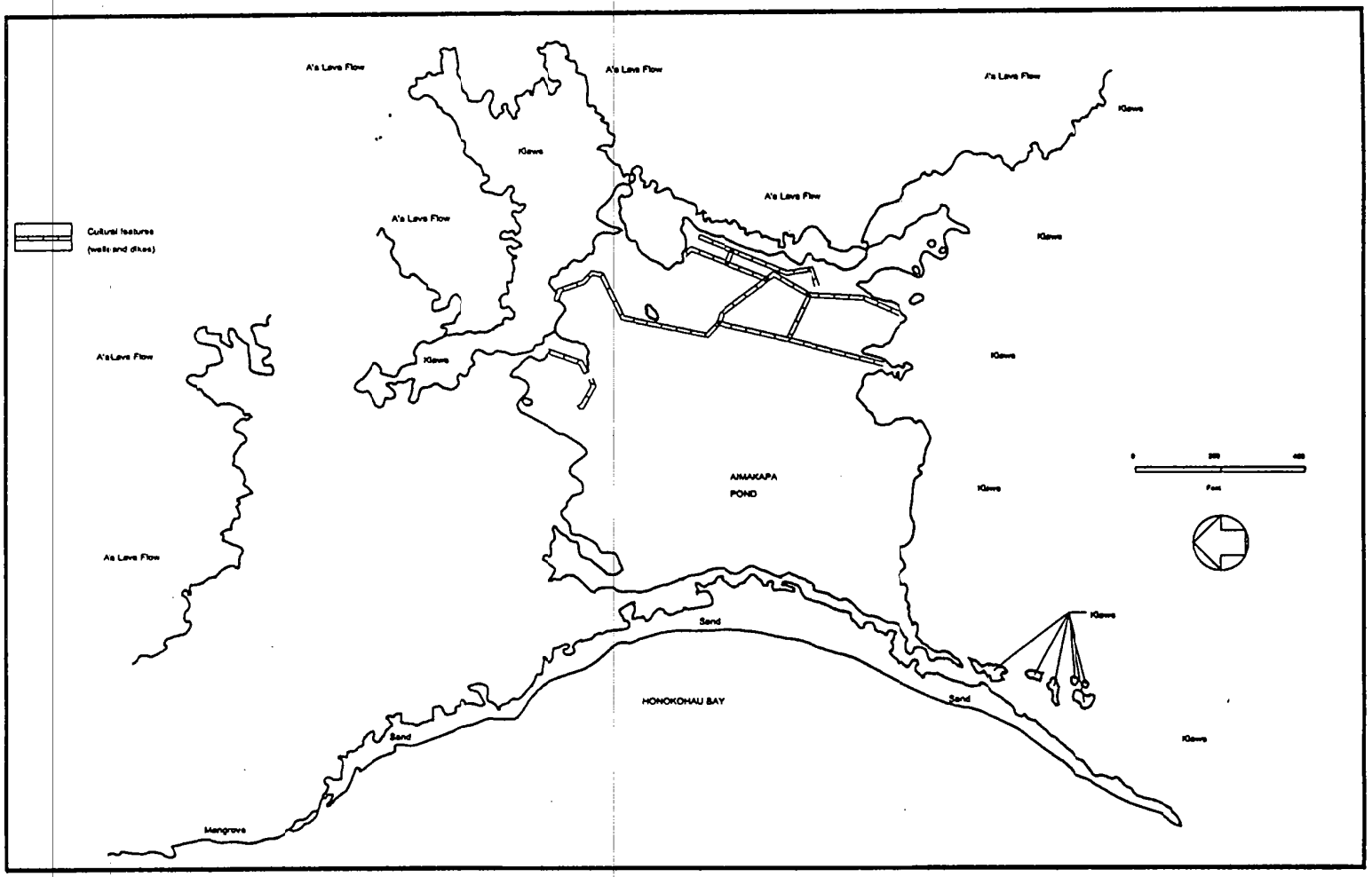

Figure 9. `Aimakapā Pond and associated cultural features, Kaloko-Honokōhau National Historical Park, Hawai`i (from Park GMP, 1994).

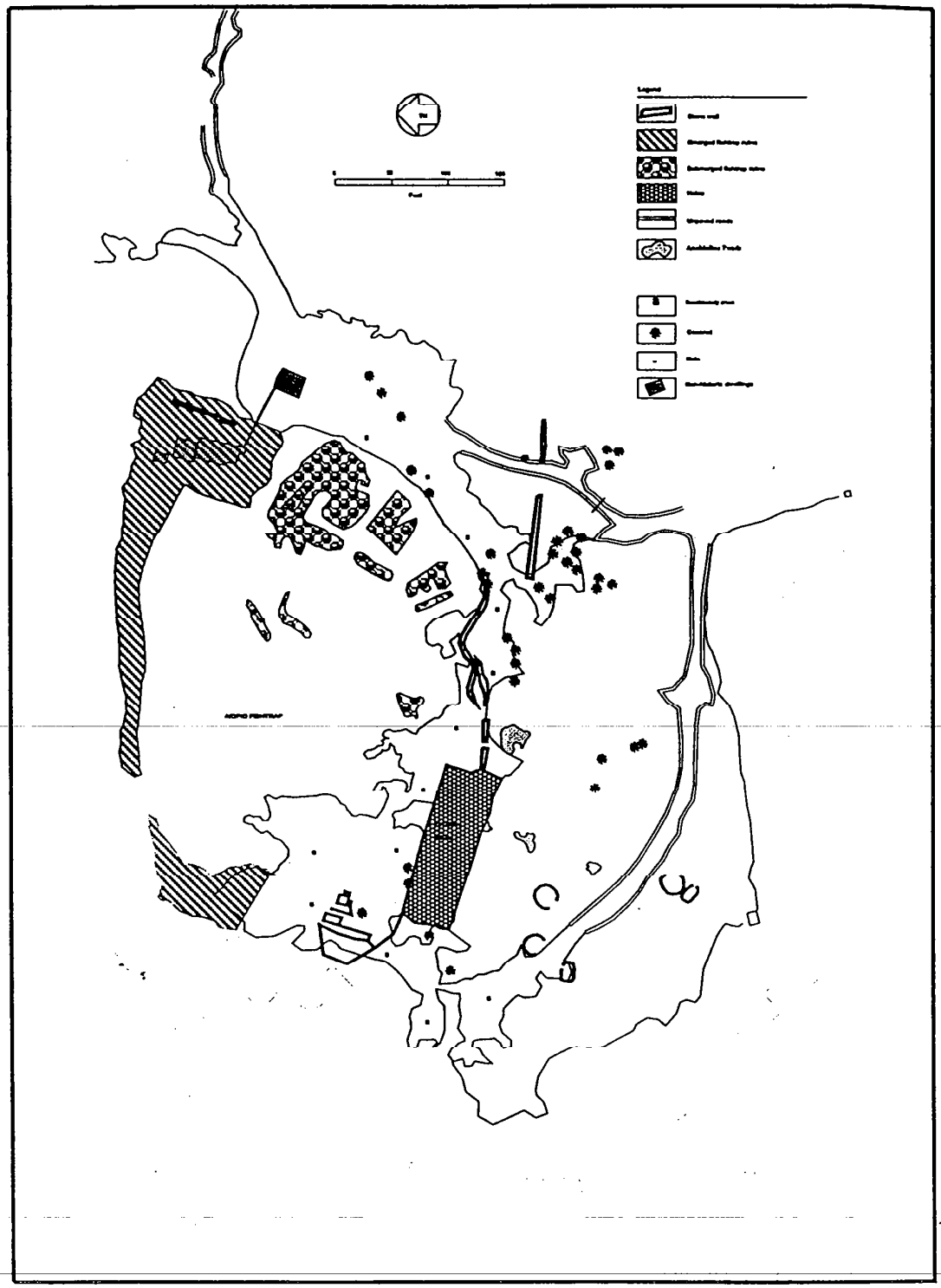

Figure 10. `Ai`opio Fishtrap and Pu`uoina Heiau, Kaloko-Honokōhau National Historical Park, Hawai`i.

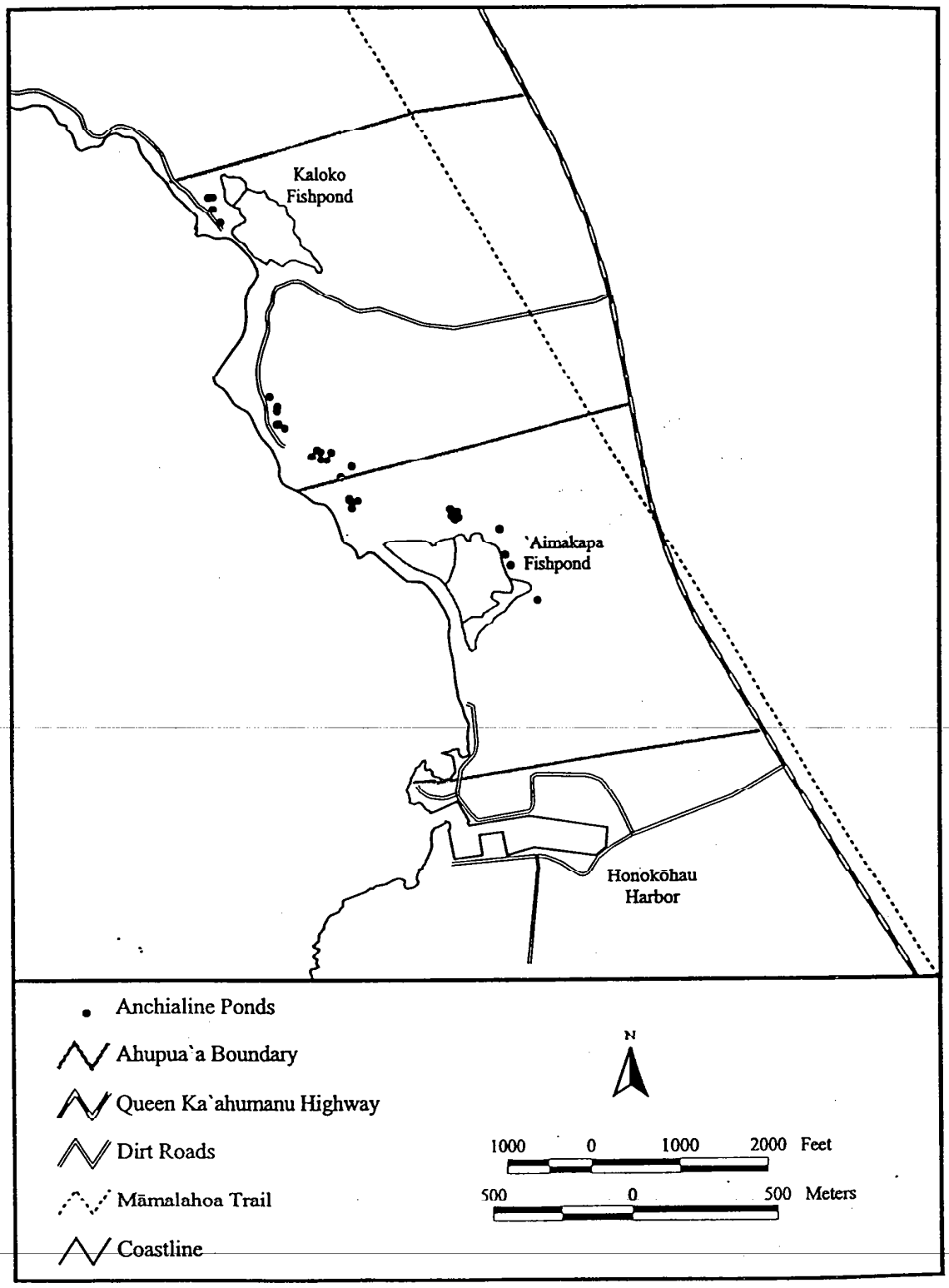

Figure 11. Anchialine pool resources of Kaloko-Honokōhau National Historical Park, Hawai'i.

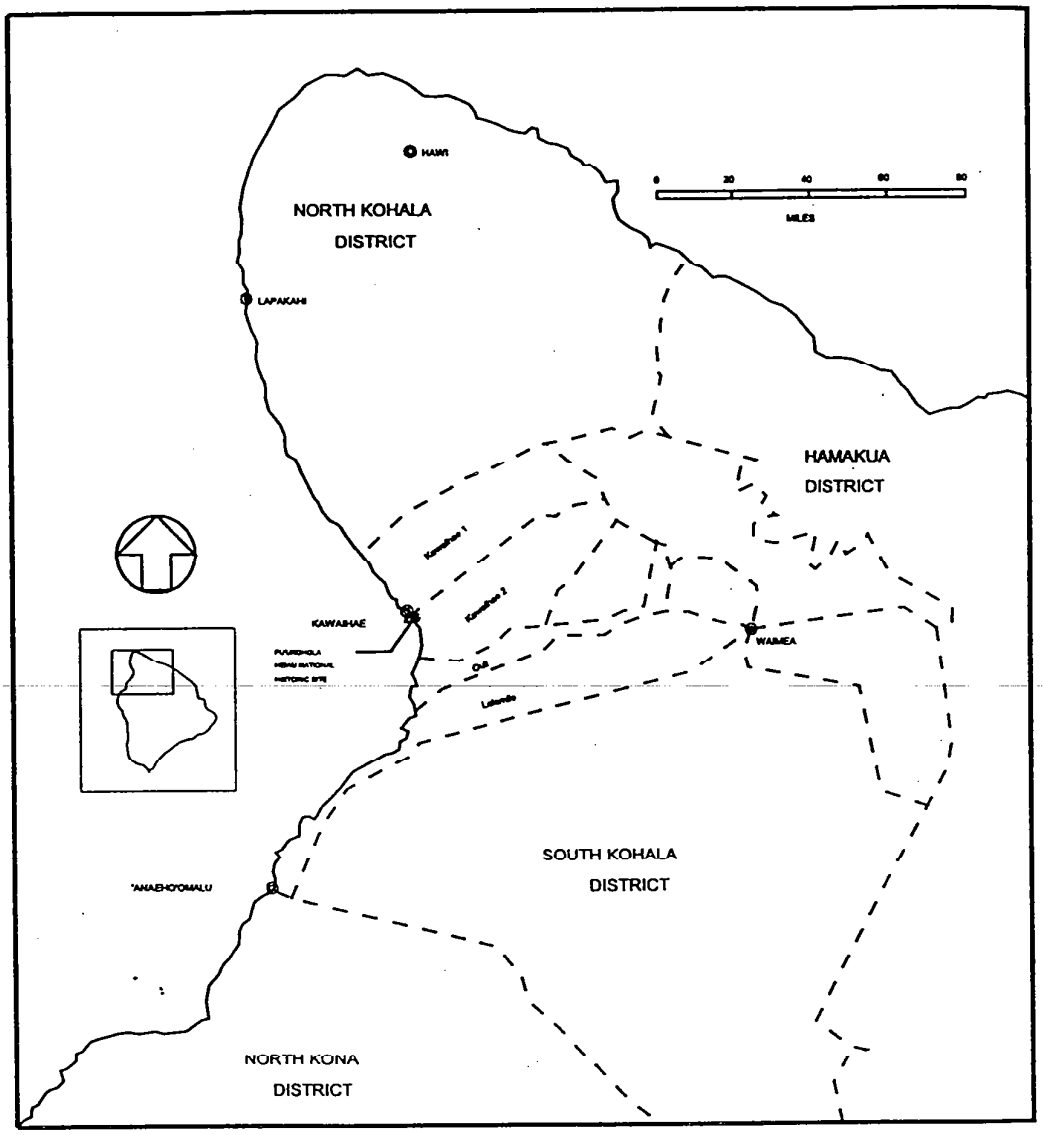

Figure 12. Northwestern districts of the island of Hawai`i, showing the location of Pu`ukoholā Heiau National Historic Site.

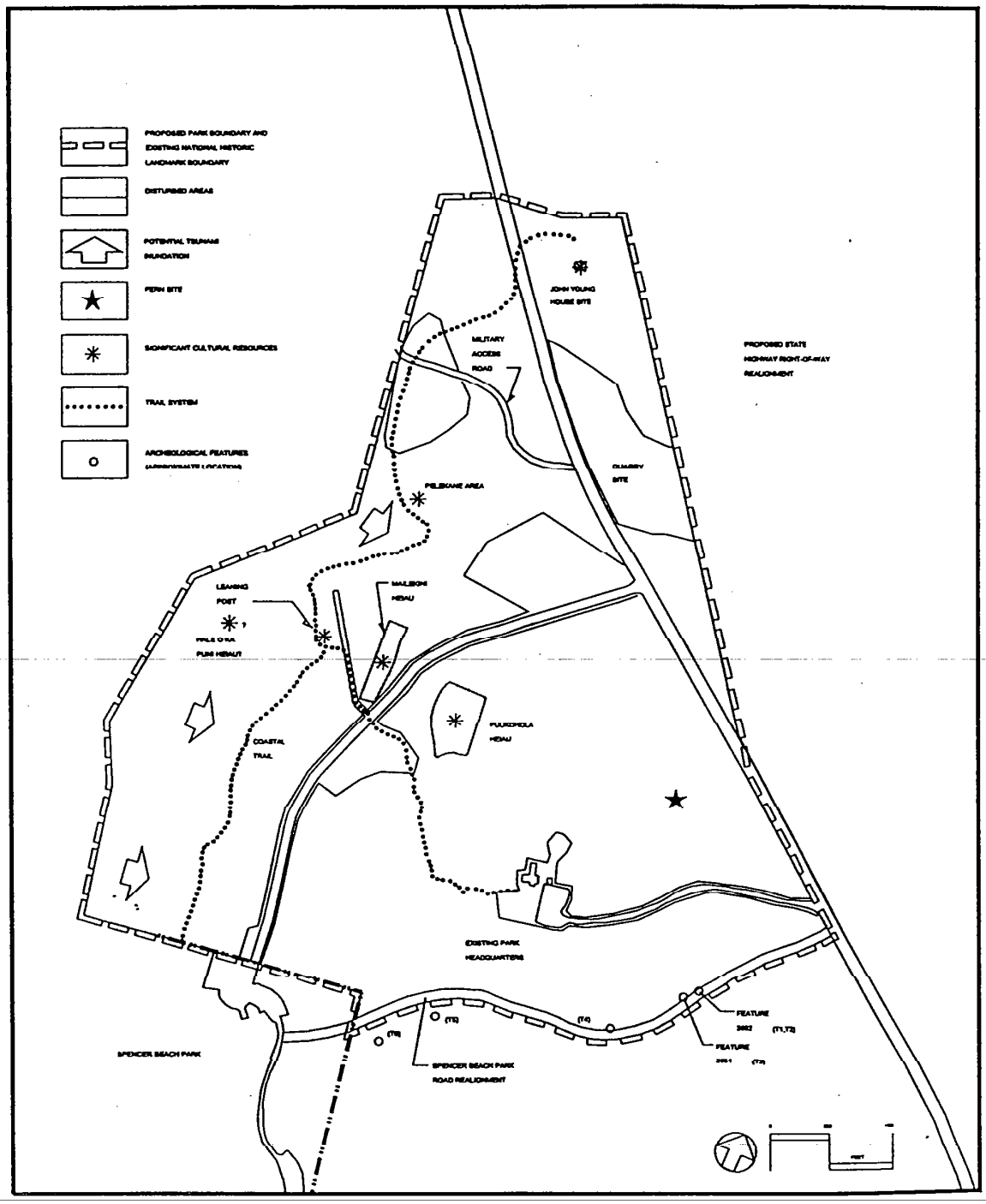

Figure 13. Significant cultural features, roads, trails, and Park headquarters in Pu`ukoholā Heiau National Historic Site, Hawai`i.

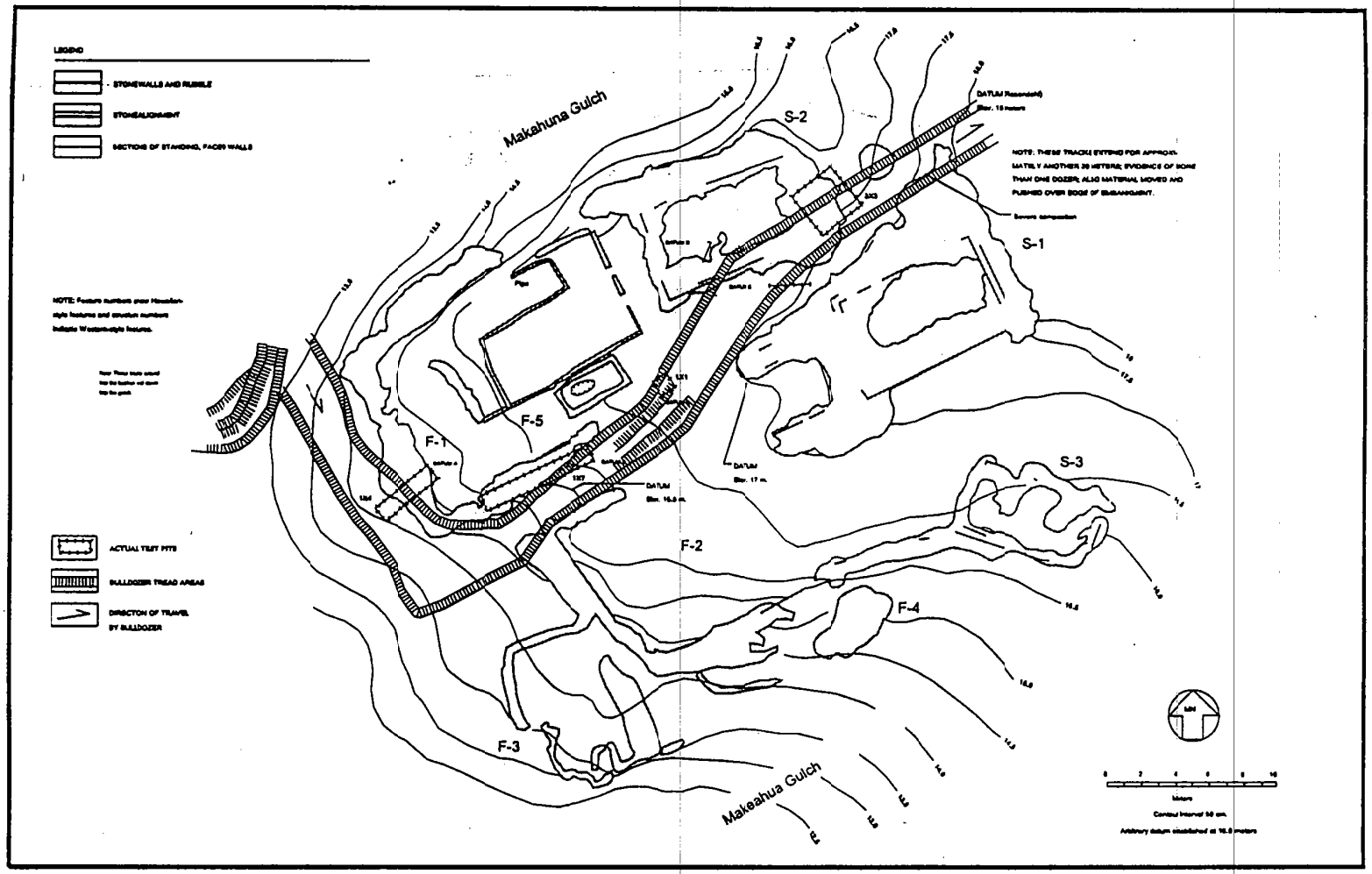

Figure 14. Archaeological features of the John Young Homestead, Pu`ukoholā Heiau National Historic Site, Hawai`i.

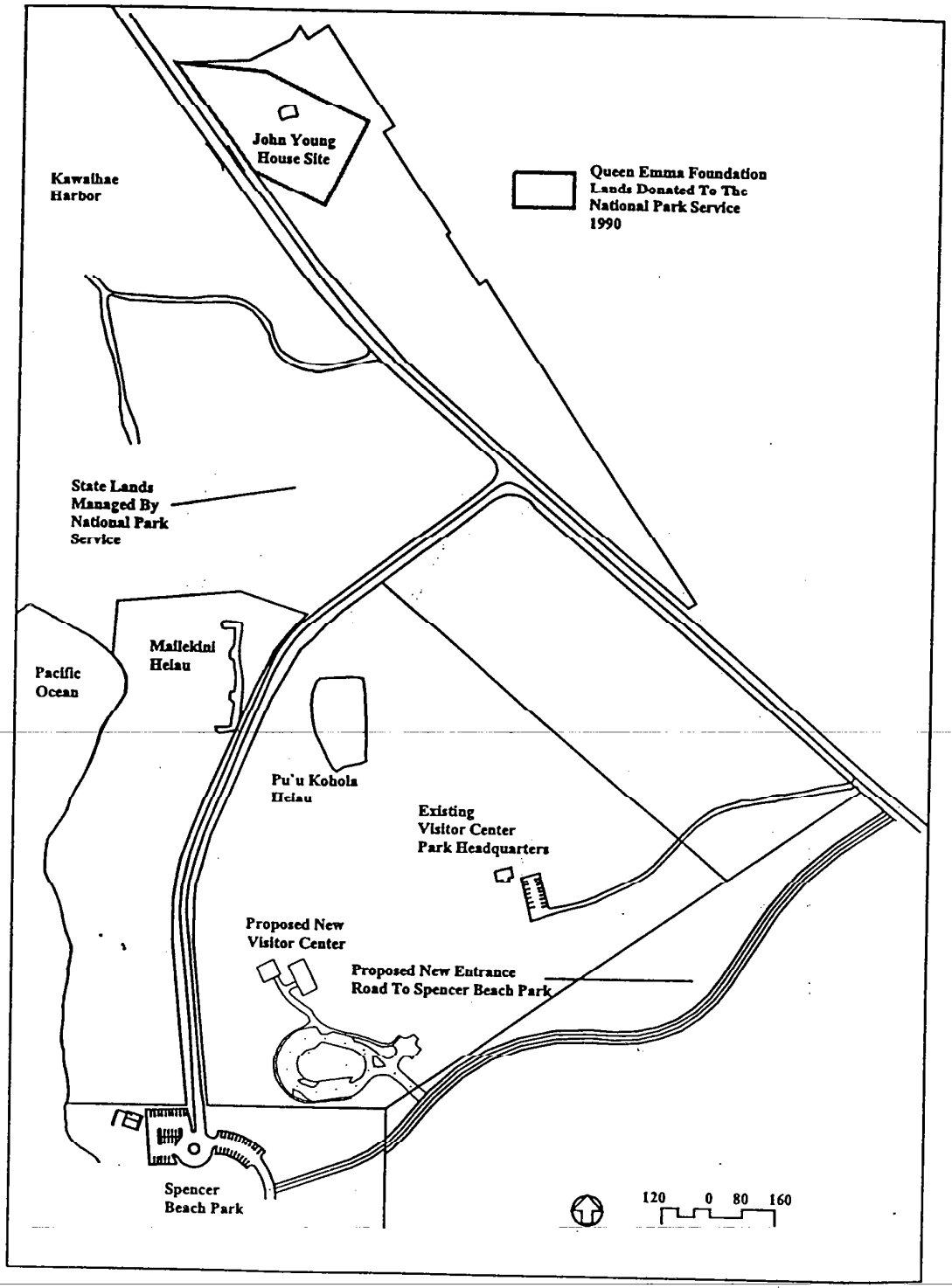

Figure 15. Proposed new visitor center and parking area at Pu'u Kohola Heiau National Historic Site, Hawai'i.

Appendix A

ALIEN PLANT SPECIES PRIORITIES FOR MANAGEMENT AT
THREE KONA NATIONAL HISTORICAL PARKS

Appendix A
Alien Plant Species Priorities for Management at
Three Kona National Historical Parks

Pu`uhonua o Hōnaunau National Historical Park

A. Alien Species to Control in Priority Sites (* are most invasive species)

Abutilon grandifolium	Hairy abutilon	Occasional near 1871 Trail and in *Ki`ilae* Village
**Acacia farnesiana*	*Klu*	Common in shrublands
Cleome gynandra	Wild spider flower	Common in open areas
Desmodium spp.	Beggarweed	Occasional in shrublands on trails
Kalanchoe pinnata	Air plant	Common in south half of Park
Indigofera suffruticosa	Indigo	Occasional in mixed shrublands
Lantana camara	Lantana	Common in shrublands
**Leucaena leucocephala*	*Ēkoa, haole koa*	Abundant in shrublands
**Melinis (Rhynchelytrum) repens*	Natal red top	Abundant in northern Park
Momordica charantia	Balsam pear, Bitter melon	Common in shrublands
**Panicum maximum*	Guinea grass	Abundant in southern Park
Passiflora foetida	Scarlet-fruited passion flower	Common in shrublands and near 1871 Trail
Passiflora suberosa	*Huehue haole*	Occasional near *Ki`ilae*
**Pithecellobium dulce*	*`Opiuma*	Common
Pluchea symphytifolia	Sourbush	Uncommon in shrublands
**Prosopis pallida*	*Kiawe*	Occasional near coast
Rivina humilis	Coral plant	Common in shrublands
**Schinus terebinthifolius*	Christmas berry	Common in northern Park
Senna occidentalis	Coffee senna	Occasional near 1871 Trail
Senna pendula	Senna	Uncommon near 1871 Trail
Talinum spp.	No common name	Common in *ēkoa* shrublands

B. Localized Alien Plant Species to Eradicate or Control Park-wide

Alternanthera pungens	Khaki weed	Uncommon near *Pu`uhonua*
Batis maritima	Pickleweed	Removed from pond
Cenchrus ciliaris	Buffelgrasss	Rare, possibly eradicated
Clusia rosea	Autograph tree	Formerly found near canoe shed, potentially invasive
Eclipta alba	False daisy	Few plants near ponds
Ficus microcarpa	Chinese banyan	Removed from near pond
Opuntia ficus-indica	Prickly pear cactus	Rare, potentially invasive
Pityrogramma austroamericana	Gold fern	One plant near canoe shed
Phoenix sp.	Date palm	Few small plants along coast
Tribulus terrestris	Puncture vine	Common along roads and trails

Appendix A (Continued)
Alien Plant Species Priorities for Management at
Three Kona National Historical Parks

Pu`uhonua o Hōnaunau National Historical Park (Continued)

C. Invasive Alien Species to Monitor for Introduction to Park

Brachiaria mutica	California grass	Eradicated in 1980s; prevent reinvasion of Park
Coccinia grandis	Ivy gourd	Currently found at *Napo`opo`o* North of Park
Pennisetum setaceum	Fountain grass	Eradicated from Park in 1980s
Alien grass species	Alien grass species	Any new alien grass species should be removed

D. Ornamental Species to Remove from Park (Some species removed in 1998)

Agave attenuata	Agave	Planted at Superintendent's house site
Ananas comosus	Pineapple	Planted at Superintendent's housesite; now removed
Aptenia cordifolia	Baby sun rose	Planted at Superintendent's house site
Bougainvillea spectabilis	Bougainvillea	Planted at Superintendent's house site
Carica papaya	Papaya	Planted at Superintendent's House site; those at base of *Alahaka Pali* should be left
Coffea arabica	Coffee	Planted near Visitor Center; now removed
Crassula sp.	Jade tree	Planted at Superintendent's house site
Crinum sp.	Spider lily	Planted near Visitor Center
Epipremnum pinnatum	Taro vine, pothos	Planted at Superintendent's house site; now removed
Gomphrena globosa	Globe amaranth	Planted at Superintendent's house site; now removed
Hibiscus sp.	Hibiscus	Planted at Superintendent's house site; now removed
Hippeastrum puniceum	Barbados lily	Planted at Superintendent's house site; now removed
Hylocereus undatus	Night-blooming Cereus	Persisting in slash heap near Administration buildings

Appendix A (Continued)
Alien Plant Species Priorities for Management at
Three Kona National Historical Parks

Pu`uhonua o Hōnaunau National Historical Park (Continued)

D. Ornamental Species to Remove from Park (Some species removed in 1998) (Continued)

Kalanchoë cf. pumila	Kalanchoë	Planted at Superintendent's house site
Noronhia emarginata	Madagascar olive	Planted near Visitor Center
Polyscias sp.	Panax	Planted at Superintendent's house site; now removed
Pleomele marginata	Money tree	Planted at Superintendent's house site
Plumeria rubra	Plumeria	Planted at Superintendent's house site; those at *Ki`ilae* should be left in place
Punica granatum	Pomegranate	Planted at Superintendent's house
Salvia sp.?	Mint, unknown sp.	Persisting behind rock wall of Superintendent's house site
Sansevieria trifasciata	Bowstring hemp	Planted at Superintendent's house site
Tradescantia spathacea	Oyster plant	Planted at Superintendent's house site
Tradescantia zebrina	Wandering jew	Planted at Superintendent's house; now removed

Kaloko-Honokōhau National Historical Park

A. Alien Species to Control in Priority Sites (* are most invasive species)

**Acacia farnesiana*	*Klu*	Common in shrublands
Achyranthes aspera	No common name	Uncommon near *`Aimakapā;* locally common in clearings
**Batis maritima*	Pickleweed	Common near ponds
Commelina benghalensis	Hairy *honohono*	Uncommon near Honokōhau
Indigofera suffruticosa	Indigo	Occasional, widespread
Lantana camara	Lantana	Common in shrublands
**Leucaena leucocephala*	*Ēkoa, haole koa*	Abundant in shrublands
Melinis (Rhynchelytrum) repens	Natal red top	Common throughout Park
**Panicum maximum*	Guinea grass	Common in southern Park
**Pennisetum setaceum*	Fountain grass	Abundant throughout Park
**Pithecellobium dulce*	*`Opiuma*	Common in shrublands

Appendix A (Continued)
Alien Plant Species Priorities for Management at
Three Kona National Historical Parks

Kaloko-Honokōhau National Historical Park (Continued)

A. Alien Species to Control in Priority Sites (* are most invasive species) (Continued)

**Pluchea symphytifolia*	Sourbush	Common near pools
**Prosopis pallida*	*Kiawe*	Abundant near ponds
Rivina humilis	Coral berrry	Locally common near *`Aimakapā*
**Schinus terebinthifolius*	Christmas berry	Common

B. Localized Alien Plant Species to Eradicate or Control Park-wide

Buddleia asiatica	Asiatic butterfly bush	Rare on side of jeep road
Cenchrus ciliaris	Buffelgrass	Rare near *Honokōhau* boundary, also in garden near *`Ai`ōpio*
Coccinia grandis	Ivy gourd	Rare in *kiawe* forest; this species should be a high priority
Desmodium tortuosum	Florida beggarweed	Rare along roads and trails
Ficus microcarpa	Chinese banyan	One tree north of *Kaloko* Pond
Grevillea robusta	Silver oak, silk oak	One tree east of *Kaloko* Pond
Hyptis pectinata	Comb hyptis	Rare on *Māmalahoa* Trail and *Hu`ehu`e* Road
Melinis minutiflora	Molasses grass	Rare near *Honokōhau* boundary
Opuntia ficus-indica	Prickly pear cactus	Uncommon, potentially invasive
Plantago major	Common plantain	Rare in garden near *`Ai`ōpio*
Rhizophora mangle	American or Red mangrove	Controlled in wetlands
Tribulus terrestris	Puncture vine	Rare on roads/trails and *`Ai`ōpio*

C. Invasive Alien Species to Monitor for Introduction to Park

Clusia rosea	Autograph tree	Removed from parking area near *Kaloko* Pond in early 1990s; likely to reinvade the Park from ornamental plantings
Ficus spp.	Banyan	Any banyan should be removed
Any alien grass species	Alien grass species	New species should be removed when they appear

D. Ornamental Species to Remove from Park

Agave attenuata	Agave	Planted near saltpan
Agave sisalana	Sisal	Planted near *Pu`uoina Heiau*

Appendix A (Continued)
Alien Plant Species Priorities for Management at
Three Kona National Historical Parks

Kaloko-Honokōhau National Historical Park (Continued)

D. Ornamental Species to Remove from Park (Continued)

Asparagaus densiflorus	Asparagus fern	Planted near saltpan
Calotropis gigantea	Crown flower	Planted near *`Ai`ōpio*
Carica papaya	Papaya	Planted near saltpan and *`Ai`ōpio*
Cleome gynandra	Wild spider flower	Planted near *Pu`uoina Heiau*
Crescentia cujete	Calabash tree	Planted near *`Ai`ōpio*
Eucalyptus sp.	Eucalyptus	Planted near saltpan
Euphorbia lactea	Mottled candlestick	Planted near saltpan
Jasminum sambac	Jasmine, pikake	Planted near saltpan
Kalanchoë tubiflora	Chandelier plant	Succulent planted near *`Ai`ōpio*
Kalanchoë spp.	Kalanchoë	Succulents dumped beside jeep road and planted near saltpan
Macadamia ternifolia	Macadamia	Planted near *`Ai`ōpio*
Monstera deliciosa	Monstera	Planted near saltpan
Nicotiana tabacum	Tobacco	Planted near *Pu`uoina Heiau;* disappeared by 1998
Olea europaea subsp. *africana*	Russian olive	Planted near saltpan
Opuntia sp.	Prickly pear cactus	Planted near saltpan
Passiflora edulis	*Liliko`i*	Planted near *`Ai`ōpio*
Philodendron sp.	Philodendron	Planted near saltpan
Pleomele marginata	Money tree	Planted near *`Ai`ōpio*
Plumeria sp.	Plumeria	Planted near *`Ai`ōpio*
Sansevieria *trifasciata*	Bowstring hemp	Planted near *Pu`uoina Heiau* and near *`Ai`ōpio*
Solanum lycopersicon	Tomato	Planted near *`Ai`ōpio*
Stapelia gigantea	Carrion flower	Planted near *Pu`uoina Heiau*
Tradescantia spathacea	Oyster plant	Planted near saltpan

Pu`ukoholā Heiau National Historic Site

A. Alien Species to Control in Priority Sites (* are most invasive species)

Abutilon grandifolium	Hairy abutilon	Occasional along trails
Alternanthera pungens	Khaki weed	Uncommon along trails
Atriplex semibaccata and *A.* spp.	Australian saltbush	Occasional
**Cenchrus ciliaris*	Buffelgrass	Abundant
Cleome gynandra	Wild spider flower	Occasional
Lantana camara	Lantana	Occasional
**Pennisetum clandestinum*	Fountain grass	Common

Appendix A (Continued)
Alien Plant Species Priorities for Management at
Three Kona National Historical Parks

Pu`ukoholā Heiau National Historic Site (Continued)

A. Alien Species to Control in Priority Sites (* are most invasive species) (Continued)

Pluchea symphytifolia	Sourbush	Uncommon
**Prosopis pallida*	*Kiawe*	Abundant

B. Localized Alien Plant Species to Eradicate or Control Park-wide

Batis maritima	Pickleweed	Occasional on stream/pond
Clusia rosea	Autograph tree	One plant near Visitor Center
Ficus microcarpa	Chinese banyan	Rare in gulch near Visitor Center
Leucaena leucocephala	*Ēkoa, koa haole*	Uncommon
Panicum maximum	Guinea grass	Rare in *kiawe* forest
Phoenix canariensis	Canary Island date	One tree on edge of pond
Ricinus communis	Castor bean	Uncommon in dry streambed
Tribulus terrestris	Puncture vine	Occasional
Triumfetta semitriloba	Sacramento bur	Uncommon along trail

C. Invasive Alien Species to Monitor for Introduction to Park

Coccinia grandis	Ivy gourd	Common near *Kailua*
Datura stramonium	Jimson weed	Reported from Park in 1982
Alien grass species		Any new alien grass species should be removed

D. Ornamental Species to Remove from Park

Ananas comosus	Pineapple	Planted at Visitor Center
Capsicum sp.	Chili pepper	Planted at Visitor Center
Carica papaya	Papaya	Planted at Visitor Center
Citrus sp.	Citrus	Planted at Visitor Center
Pleomele marginata	Money tree	Planted at Visitor Center
Samanea saman	Monkeypod	Planted at Visitor Center
Spathodea campanulata	African tulip tree	Planted at Visitor Center
Unidentified alien shrub species		Planted at Visitor Center

Appendix B

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

Appendix B

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

ANNOTATIONS AND SYMBOLS

Status:

E=Endemic	=	Native and unique to the Hawaiian Islands
I=Indigenous	=	Native to the Hawaiian Islands and other lands
P=Polynesian	=	Introduced by Polynesians prior to 1778
A=Alien	=	Introduced to Hawai`i after 1778, non-indigenous, exotic

Symbols and Abbreviations:

PUHO	=	Pu`uhonua o Hōnaunau National Historical Park
KAHO	=	Kaloko-Honokōhau National Historical Park
PUHE	=	Pu`ukoholā Heiau National Historic Site

Abundance Ratings:

A	=	Abundant
C	=	Common, numerous and widespread
O	=	Occasional, scattered in many localities in Park
U	=	Uncommon, infrequent, few plants scattered or localized
R	=	Rare, one or very few plants seen
lc	=	Localized at one or few sites
p	=	Planted in Park, apparently not naturalized
?	=	Previously listed as present in the Park, but not found during most recent survey.

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
FERNS AND FERN ALLIES				
DRYOPTERIDACEAE - WOODFERN FAMILY (NEPHROLEPIDOIDEAE- SWORDFERN SUBFAMILY)				
Nephrolepis exaltata (L.) Schott *Kupukupu* Not seen in KAHO or PUHO in 1992-94.	I	?	?	-
Nephrolepis multiflora (Roxb.) F. M. Jarrett ex C. V. Morton [Syn: *Nephrolepis hirsutula* (Forst. f.) Presl] Scaly swordfern	A	C	O	U
OPHIOGLOSSACEAE - ADDER'S TONGUE FERN FAMILY				
Ophioglossum polyphyllum A. Braun [Syn: *Ophioglossum concinnum* Brack.] *Pololei*	I	-	-	R
POLYPODIACEAE - POLYPODY FAMILY				
Phymatosorus grossus (Langsd. & Fisch.) Brownlie *Laua`e*	A	C	R	-
Polypodium pellucidum Kaulf. *`Ae* Reported KAHO 1990; not seen in 1992-94.	E	-	?	-
PSILOTACEAE - WHISK FERN FAMILY				
Psilotum nudum (L.) P. Beauv. *Moa*, whisk fern	I	U	R	R

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
FERNS AND FERN ALLIES				
PTERIDACEAE -PTERIS FAMILY				
Doryopteris decora Brack. *`Iwa`iwa* Reported PUHE 1977; not seen in 1992-94.	E	R	-	?
Pityrogramma austroamericana Domin Gold fern Addition to PUHO flora in 1998.	A	R	-	-
FLOWERING PLANTS - DICOTYLEDONS (MAGNOLIOPSIDA)				
ACANTHACEAE - ACANTHUS FAMILY				
Barleria cristata L. Philippine violet	A	-	R	-
AIZOACEAE - FIG-MARIGOLD FAMILY				
Aptenia cordifolia Baby sun rose Planted at one PUHO site.	A	R, p	-	-
Sesuvium portulacastrum (L.) L. *`Ākulikuli*, sea purslane	I	U	C	O
Tetragonia tetragonioides (Pall.) Kuntze New Zealand spinach Reported PUHE 1982; not seen in 1992-94.	A	-	-	?
AMARANTHACEAE - AMARANTH FAMILY				
Achyranthes aspera L. No common name	A	-	U	-

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
AMARANTHACEAE - AMARANTH FAMILY (Continued)				
Alternanthera pungens Kunth [Syn: *Alternanthera repens* (L.)Link] Khaki weed	A	U	-	U
Amaranthus dubius Mar. Ex Thell. Spleen amaranth Reported PUHE 1977; not seen in 1992-94.	A	-	-	?
Amaranthus lividus L. subsp. *polygonoides* (Moq.) Probst Amaranth	A	-	U	U
Amaranthus spinosus L. Spiny amaranth	A	U	R	U
Amaranthus viridis L. Slender amaranth	A	O	U	-
Gomphrena globosa L. Globe amaranth Former planting at PUHO; removed.	A	U, p	-	-
ANACARDIACEAE - MANGO FAMILY				
Schinus terebinthifolius Raddi Christmas berry	A	C	C	-
APOCYNACEAE - DOGBANE FAMILY				
Catharanthus roseus (L.) G. Don Madagascar periwinkle	A	O	O	-
Plumeria rubra L. Plumeria, frangipani	A	O, p	R, p	-
ARALIACEAE - GINSENG FAMILY				
Polyscias sp. Panax Former planting at PUHO; removed.	A	R, p	-	-

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
ASCLEPIADACEAE - MILKWEED FAMILY				
Calotropis gigantea (L.) W. T. Aiton Crown flower Addition to KAHO flora in 1997.	A	-	R, p	-
Stapelia gigantea N. E. Brown Zulu-giant, carrion flower Addition to KAHO flora in 1997.	A	-	R, p	-
ASTERACEAE (COMPOSITAE) - SUNFLOWER FAMILY				
Ageratum conyzoides L. Ageratum	A	R	U	-
Bidens cynapiifolia Kunth West Indian beggar's tick Reported PUHE 1977; not seen in 1992-94.	A	C	U	?
Bidens micrantha Gaud. subsp. *ctenophylla* (Sherff) Nagata & Ganders *Ko`oko`olau* A candidate endangered species.	E	-	R	-
Bidens pilosa L. Spanish needle	A	U	U	-
Conyza bonariensis (L.) Cronq. Hairy fleabane	A	-	-	U
Eclipta alba (L.) Hassk. False daisy	A	R	-	-
Emilia fosbergii Nicolson *Pualele*	A	U	R	U
Emilia sonchifolia (L.) DC Flora's paintbrush Reported PUHE 1977; not seen in 1992-94.	A	O	R	?
Gnaphalium purpureum L. Purple cudweed Reported PUHO 1986 and PUHE 1977; not seen in 1992-94.	A	?	-	?

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
ASTERACEAE - SUNFLOWER FAMILY (Continued)				
Pluchea symphytifolia (Mill.) Gillis [Syn: *Pluchea odorata* (L.) Cass.] Sourbush, shrubby fleabane	A	U	O	U
Reichardia picroides (L). Roth Picridium Reported KAHO 1990; not seen in 1992-94.	A	-	?	-
Sonchus oleraceus L. Sow thistle Reported PUHE 1977; not seen in 1992-94.	A	-	-	?
Tridax procumbens L. Coat buttons	A	U	U	R
Xanthium strumarium L. [Syn: *Xanthium saccharatum* Wallr.] Cocklebur, *kīkānia* Reported PUHE 1982; not seen in 1992-94.	A	-	-	?
BATACEAE - SALTWORT FAMILY				
Batis maritima L. Pickleweed, *`ākulikuli kai* Now removed from PUHO.	A	U, lc	A, lc	O, lc
BIGNONIACEAE - BIGNONIA FAMILY				
Crescentia cujete L. Calabash tree Addition to KAHO flora in 1997.	A	R, p	R, p	-
Spathodea campanulata P. Beauv. African tulip tree	A	-	-	R, p?

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
BORAGINACEAE - BORAGE FAMILY				
Cordia subcordata Lam. *Kou*	P	U	U	R, p
Heliotropium amplexicaule Vahl Heliotrope Addition to KAHO flora in 1997.	A	-	R	-
Heliotropium anomalum Hook. & Arnott subsp. *argenteum* A. Gray *Hinahina* Reported KAHO1990; not seen in1992-94.	I	-	?	-
Heliotropium curassavicum L. *Kīpūkai, nena*, seaside heliotrope	I	?	U	R
Myosotis azorica H.C. Wats. ex Hook. Forget-me-not Reported PUHO 1986; not seen in 1992-94.	A	?	-	-
Tournefortia argentea L. fil. [Syn: *Messerschmidia argentea* (L. fil) I. M. Johnst.] Tree heliotrope	A	R	A, Ic	O
BRASSICACEAE - MUSTARD FAMILY				
Lepidium virginicum L. Wild peppergrass	A	O	-	-
BUDDLEIACEAE - BUTTERFLY BUSH FAMILY				
Buddleia asiatica Lour. Asiatic butterfly bush	A	-	R	-
CACTACEAE - CACTUS FAMILY				
Hylocereus undatus (Haw.) Britton & Rose [Syn: *Cereus undatus* Haw.] Night-blooming cereus	A	U, p	-	-

CHECKLIST OF VASCULAR PLANT SPECIES IN THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
CACTACEAE - CACTUS FAMILY (Continued)				
Opuntia ficus-indica (L.) Mill. (Syn: *Opuntia megacantha* Salm-Dyck] Prickly pear cactus, *pānini* Possibly removed from PUHO.	A	R	U	-
CAPPARACEAE - CAPER FAMILY				
Capparis sandwichiana DC *Pua pilo, maiapilo* Former candidate endangered species; now species of concern.	E	R	O	-
Cleome gynandra L. [Syn: *Gynandropsis gynandra* (L.) Briq.] Wild spider flower	A	C	R	O
Cleome spinosa L. *Honohina* Reported PUHO 1986, not seen in 1992-94.	I	?	-	-
CARICACEAE - PAPAYA FAMILY				
Carica papaya L. Papaya Addition to KAHO flora in 1997.	A	U	R, p	R, p
CHENOPODIACEAE - GOOSEFOOT FAMILY				
Atriplex eardleyae Aellen[1] Saltbush [Identified as *A. semibaccata* R. Br. in 1986]. Reported PUHO 1986; not seen in1992-94.	A	?	-	-

CHECKLIST OF VASCULAR PLANT SPECIES IN THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
CHENOPODIACEAE - GOOSEFOOT FAMILY (Continued)				
Atriplex maximowicziana Makino[2] Saltbush [Identified as *A.? johnstonii* Wolf in 1977]. Reported PUHE 1977; not seen 1992-94.	A	-	-	?
Atriplex semibaccata R. Br. Australian saltbush	A	-	-	O
Atriplex suberecta Verd. [Syn: *Atriplex muelleri* Benth.] Saltbush	A	-	-	U
Chenopodium album L. Pigweed, lamb's quarters Reported PUHO 1986; not seen in 1993-94.	A	?	-	-
Chenopodium ambrosioides L. Mexican tea Reported KAHO 1990; not seen in 1992-94.	A	-	?	-
Chenopodium murale L. Nettle-leaved goosefoot, *`āheahea*	A	U	O	U
Chenopodium oahuense (Meyen) Aellen *`Āheahea, `Āweoweo* Reported PUHE 1977; not seen in 1992-94.	E	-	-	?
CLUSIACEAE (GUTTIFERAE) - MANGOSTEEN FAMILY				
Calophyllum inophyllum L. *Kamani*	P	U, p	-	U, p
Clusia rosea Jacq. Autograph tree Now removed from KAHO and PUHO. One or few at PUHE.	A	R	R	R

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
COMBRETACEAE - INDIAN ALMOND FAMILY				
Terminalia catappa L. Tropical almond, false *kamani*	A	O	-	-
CONVOLVULACEAE - MORNING GLORY FAMILY				
Ipomoea batatas (L.) Lam. *`Uala*, sweet potato Addition to KAHO flora in 1997.	P	R, p	R, p	R, p
Ipomoea indica (J. Burm.) Merr. [Syn: *Ipomoea congesta* R. Br.] *Koali `awa, koali `awahia* Reported PUHE 1977; not seen in 1992-94.	I		O	?
Ipomoea pes-caprae (L.) R. Br. subsp. *brasiliensis* (L.) Ooststr. [Syn: *Ipomoea brasiliensis* (L.) Sweet] *Põhuehue*, beach morning glory	I	O	O	U
Ipomoea tuboides Degener & Ooststr. Hawaiian moon flower	E	R	-	-
Ipomoea violacea L. No common name	A	-	R	-
*Jacquemontia ovalifolia (*Choisy) H.Hallier subsp. *sandwicensis* (A. Gray) K. Robertson [Syn: *Jacquemontia sandwicensis* A. Gray] *Pā`ū o Hi`iaka*	E	-	U	R
Merremia aegyptia (L.) Urb. Hairy merremia	A?	R	-	U
CRASSULACEAE - ORPINE FAMILY				
Crassula sp. Jade tree	A	R, p	-	-

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
CRASSULACEAE - ORPINE FAMILY (Continued)				
Echeveria sp.? Echeveria Planted at one site at PUHO; to be removed.	A	R, p	-	-
Kalanchoë daigremontiana Hamet & Perrier Devil's backbone Few plants scattered near saltpan at KAHO; addition to flora in 1998.	A	-	R, p	-
Kalanchoë pinnata (Lam.) Pers. [Syn: *Bryophyllum pinnatum* (Lam.) Kurz] Air plant Few plants found near saltpan at KAHO; common at PUHO.	A	C	R	-
Kalanchoë pumila Dwarf purple kalanchoe One patch planted near saltpan at KAHO; addition to flora in 1998.	A	-	R, p	-
Kalanchoë tubiflora (Harv.) Raym.-Hamet [Syn: *Bryophyllum tubiflorum* Harv.] Chandelier plant Reported KAHO 1990; not seen in 1992-94; found as planting near *`Ai`opio* in 1997.	A	-	R, p	-
CUCURBITACEAE - GOURD FAMILY				
Citrullus sp. *Ipu* Reported PUHE 1977; not seen in 1992-94.	A	-	-	?
Coccinia grandis (L.) Voigt Ivy gourd, scarlet-fruited gourd	A	-	R	-
Cucumis dipsaceus Ehrenb. ex Spach. Hedgehog gourd, teasel gourd Reported PUHO 1986; not seen in 1992-94.	A	?	-	R

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
CUCURBITACEAE - GOURD FAMILY (Continued)				
Lagenaria siceraria (Molina) Standl. *Ipu,* bottle gourd Found near *Kaloko* Pond in 1997.	P	-	R	R, p
Momordica charantia L. Balsam pear, bitter melon	A	C	R	-
EUPHORBIACEAE - SPURGE FAMILY				
Aleurites moluccana (L.) Willd. *Kukui*, candlenut Addition to KAHO flora in 1997.	P	O, p	R, p	R, p
Chamaesyce hirta (L.) Millsp. [Syn: *Euphorbia hirta* L.] Hairy spurge	A	O	O	U
Chamaesyce hypericifolia (L.) Millsp. [Syn: *Euphorbia glomerifera* (Millsp.) Wheeler] Graceful spurge	A	O	R	R
Chamaesyce prostrata (Aiton) Small (Syn: *Euphorbia prostrata*) Prostrate spurge	A	O	R	U
Euphorbia heterophylla L. [Syn: *Euphorbia geniculata* Ort.]	A	-	-	R
Euphorbia lactea Haw. Mottled candlestick One succulent planted near saltpan at KAHO; addition to flora in 1998.	A	-	R, p	-
Euphorbia sp. Unidentified ornamental species	A	-	R	-
Phyllanthus debilis Klein ex Willd. Niruri Reported near KAHO1990; not seen 1992-94.	A		?	
Ricinus communis L. Castor bean	A	-	-	U

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
FABACEAE (LEGUMINOSAE) - PEA FAMILY				
Acacia farnesiana (L.) Willd. *Klu*	A	C	C	-
Acacia koa A. Gray *Koa*	E	-	-	R, p
Chamaecrista nictitans (L.) Moench subsp. *patellaria* (DC ex Collad.) H. Irwin & Barneby var. *glabrata* (Vogel) H. Irwin & Barneby [Syn: *Cassia leschenaultiana* DC] Partridge pea	A	O	U	-
Crotalaria pallida Aiton Smooth rattlepod	A	U	-	-
Delonix regia (Bojer ex Hook.) Raf. Royal poinciana Planted along highway near KAHO.	A	-	R, p	-
Desmanthus virgatus (L.) Willd. Slender mimosa Reported PUHE 1977; not seen in 1992-94.	A	-	-	?
Desmodium cajanifolium (Kunth) DC No common name	A	O	-	-
Desmodium sandwicense E. Mey. [Syn: *Desmodium uncinatum* (Jacq.) DC] Spanish clover	A	-	-	U
Desmodium tortuosum (Sw.) DC Florida beggarweed	A	O	R	-
Desmodium triflorum (L.) DC Three-flowered beggarweed	A	-	U	-
Erythrina sandwicensis Degener *Wiliwili* Planted at PUHE.	E	-	-	R, p
Erythrina variegata L. Coral tree Planted along highway at KAHO.	A	-	U, p	-
Indigofera suffruticosa Mill. Indigo	A	O	O	-

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
FABACEAE - PEA FAMILY (Continued)				
Leucaena leucocephala (Lam.) de Wit *Ēkoa, koa haole*	A	A	A	U
Medicago lupulina L. Black medick	A	-	-	U
Pithecellobium dulce (Roxb.) Benth. *`Opiuma*, Manila tamarind	A	C	C	-
Prosopis pallida (Humb. & Bonpl. ex Willd.) Kunth *Kiawe*, mesquite Most abundant tree in PUHE and KAHO.	A	O	A	A
Samanea saman (Jacq.) Merr. Monkeypod Planted at PUHE Visitor Center.	A	O	-	R, p
Senna occidentalis (L.) Link Coffee senna	A	O	R	-
Senna pendula (Humb. & Bonpl. ex Willd.) H. Irwin & Barnbeby [Syn: *Cassia bicapsularis* L.]	A	U	-	-
Tamarindus indica L. Tamarind	A	U, p?	-	?
Tephrosia purpurea (L.) Pers. var. *purpurea* *`Auhuhu*	P	U	U	-
GOODENIACEAE - GOODENIA FAMILY				
Scaevola sericea Vahl [Syn: *Scaevola taccada* Roxb.] *Naupaka kahakai* Planted at PUHE.	I	C	C	R
LAMIACEAE (LABIATAE) - MINT FAMILY				
Hyptis pectinata (L.) Poit. Comb hyptis	A	-	R	-

CHECKLIST OF VASCULAR PLANT SPECIES IN THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
LAMIACEAE - MINT FAMILY (Continued)				
Ocmium gratissimum L. Wild basil Reported PUHO 1986; not seen in 1992-93.	A	?	-	-
Plectranthus parviflorus Willd. Spurflower, *`ala`alawainui pua kī*	I	O	-	-
Salvia occidentalis Sw. West Indian sage	A	-	R	-
Salvia sp. Unknown Escaped from cultivation; persists at one site in PUHO.	A	R	-	-
LOGANIACEAE - STRYCHNINE FAMILY				
Fragraea berteriana Gray ex Benth. *Pua kenikeni* Reported PUHO 1986; not seen in 1994.	A	R, p	-	-
MALVACEAE - MALLOW FAMILY				
Abutilon grandifolium (Willd.) Sweet Hairy abutilon	A	O	U	O
Gossypium barbadense L. Cotton Reported PUHO 1986; not seen in 1992-94; no longer in the Park?	A	?	-	-
Gossypium tomentosum Nutt. ex Seem. *Ma`o*, Hawaiian cotton Planted near PUHE Visitor Center.	E	-	-	R, p
Hibiscus brackenridgei A. Gray subsp. *brackenridgei* *Ma`o hau hele* Planted near PUHE Visitor Center.	E	-	-	R, p
Hibiscus tiliaceus L. *Hau* Common at *`Aimakapā*, KAHO.	I	-	C, Ic	-
Hibiscus sp. Former planting at PUHO.	A	R, p	-	-

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
MALVACEAE - MALLOW FAMILY (Continued)				
Malvastrum coromandelianum (L.) Garcke subsp. *coromandelianum* False mallow	A	O	R	-
Sida fallax Walp. *`Ilima*	I	U	C	U
Sida spinosa L. Prickly sida	A	-	U	-
Thespesia populnea (L.) Sol. ex Correa *Milo* Localized near wetlands/ponds; also planted at PUHE.	I	U	A, lc	O
MOLLUGINACEAE - CARPETWEED FAMILY				
Mollugo sp. Carpetweed Reported PUHE 1982; not seen in 1992-94.	A	-	-	?
MORACEAE - MULBERRY FAMILY				
Artocarpus altilis (Parkins ex Z.) Fosb. *`Ulu*, breadfruit New addition to KAHO flora 1997.	P	-	R, p	-
Broussonetia papyrifera (L.) Venten. *Wauke*, paper mulberry Planted at PUHO and PUHE; new addition to KAHO flora in 1997.	P	U, p	R, p	R, p
Ficus benjamina L. Weeping fig Reported near KAHO in 1990; not seen in Park in 1992-93 survey.	A		?	
Ficus microcarpa L. fil. Chinese banyan Only one tree each at PUHO and KAHO; now removed from PUHO.	A	R	R	R

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
MYOPORACEAE - MYOPORUM FAMILY				
Myoporum sandwicense A. Gray *Naio*	I	-	U	-
MYRTACEAE - MYRTLE FAMILY				
Eucalyptus sp. Eucalyptus One tree near salt pan at KAHO.	A	-	R, p	-
NYCTAGINACEAE - FOUR-O'CLOCK FAMILY				
Boerhavia coccinea Mill. No common name	A	O	O	U
Boerhavia repens L. [Syn: *Boerhavia diffusa* L., in part] *Alena* *B. diffusa* reported PUHE 1977; not seen in 1992-94 survey.	I	-	U	?
Bougainvillea glabra Choisy Lesser bougainvillea Planted on rock berm along KAHO boundary with *Honokōhau* Harbor.	A	-	U, p	-
Bougainvillea spectabilis Willd. Bougainvillea Planted along boundary at KAHO; removed from one site in PUHO.	A	U, p	U, p	-
OLEACEAE - OLIVE FAMILY				
Jasminum sambac (L.) Aiton *Pīkake*, Arabian jasmine Reported PUHO 1986; not seen in 1992-94. New addition to KAHO in 1998.	A	?	R, p	-
Noronhia emarginata (Lam.) Stadm. Madagascar olive	A	R, p	-	-

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
OLEACEAE - OLIVE FAMILY (Continued)				
Olea europaea L. subsp *africana* (Mill.) P. Green Russian olive New addition to KAHO in 1998; planted near salt pan.	A	-	R, p	-
OXALIDACEAE - WOOD SORREL FAMILY				
Oxalis corniculata L. Yellow wood sorrel, *`ihi`ai*	P?	U	-	R
PAPAVERACEAE - POPPY FAMILY				
Argemone glauca (Nutt. ex Prain) Pope var. *decipiens* Ownbey *Pua kala*, Hawaiian prickly poppy Probably planted at PUHO.	E	R, p?	R	-
PASSIFLORACEAE - PASSION FLOWER FAMILY				
Passiflora edulis Sims *Liliko`i* Addition to KAHO flora in 1997.	A	-	R, p	-
Passiflora foetida L. Love-in-a-mist, scarlet-fruited passion flower	A	C	U	R
Passiflora suberosa L. *Huehue haole*	A	O	-	-
PHYTOLACCACEAE - POKEWEED FAMILY				
Rivina humilis L. Coral berry	A	C	C, lc	-

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
PIPERACEAE - PEPPER FAMILY				
Peperomia leptostachya Hook. & Arnott *`Ala`ala wai nui*	I	O	-	-
PLANTAGINACEAE - PLANTAGO FAMILY				
Plantago australis Lam. subsp. *hirtella* (Kunth) Rahn Dwarf plantain	A	-	-	U
Plantago lanceolata L. Narrow-leaved plantain In PUHE Visitor Center lawn.	A	-	-	U
Plantago major L. Broad-leaved plantian, *laukahi* New addition to KAHO flora in 1997.	A	-	R	-
PLUMBAGINACEAE - LEADWORT FAMILY				
Plumbago zeylanica L. *`Ilie`e* Reported PUHO 1986; not seen in 1992-94.	I	?	U	-
POLYGONACEAE - BUCKWHEAT FAMILY				
Cocoloba uvifera (L.) L. Sea grape Reported PUHO 1986; not seen in 1992-94; no longer in Park?	A	?	-	-

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
PORTULACACEAE - PURSLANE FAMILY				
Portulaca lutea Sol. ex G. Forster *`Ihi* Reported KAHO 1990; not seen in 1992-94.	I	-	?	-
Portulaca oleracea L. Pigweed, common purslane	A	O	O	U
Portulaca pilosa L. [Syn: *Portulaca cyanosperma* Egler] No common name	A	O	O	U
Talinum paniculatum (Jacq.) Gaertn. Jewels of Opar	A	C	-	-
Talinum triangulare (Jacq.) Willd. No common name	A	C	U	-
PROTEACEAE - PROTEA FAMILY				
Grevillea robusta A. Cunn. ex R. Br. Silk oak, silver oak One tree in seen in KAHO in 1992-93, east of *Kaloko* Pond.	A	-	R	-
Macadamia ternifolia F. Muell. Macadamia nut Addition to KAHO flora in 1997.	A	-	R, p	-
PUNIACEAE - POMEGRANATE FAMILY				
Punica granatum L. Pomegranate One shrub planted at former Superintendent's house in PUHO.	A	R, p	-	-

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
RHIZOPHORACEAE - MANGROVE FAMILY				
Rhizophora mangle L. American or red mangrove Actively managed and removed from KAHO; formerly abundant.	A	-	U	-
RUBIACEAE - COFFEE FAMILY				
Canthium odoratum (G. Forster) Seem. *Alahe`e* Now called *Psydrax odorata*.	I	-	U	-
Coffea arabica L. Arabian coffee Planted near PUHO Visitor Center; removed by 1998.	A	U, p	-	-
Hedyotis corymbosa (L.) Lam. No common name In lawn at PUHE Visitor Center.	A	U	-	U
Morinda citrifolia L. *Noni*, Indian mulberry Widespread at PUHO & KAHO; planted at PUHE.	P	C	C	R, p
Spermacoce assurgens Ruiz & Pav. [Syn: *Borreria laevis* (Lam.) Griseb.] Buttonweed	A	R	-	-
Spermacoce sp. Buttonweed In lawn at PUHE Visitor Center.	A	-	-	U
RUTACEAE - RUE FAMILY				
Citrus sinensis (L.) Osbeck Orange Planted at PUHO house site.	A	R, p	-	-
Citrus sp. Citrus, species unknown Planted at PUHE and PUHO.	A	R, p	-	R, p

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
SAPINDACEAE - SOAPBERRY FAMILY				
Dodonaea viscosa Jacq. [Syn: *Dodonaea eriocarpa* Sm.] *`A`ali`i* Few natural individuals at KAHO; planted at PUHE and PUHO.	I	R, p	R	R, p
SCROPHULARIACEAE - FIGWORT FAMILY				
Bacopa monnieri (L.) Wettst. *`Ae`ae*, water hyssop Aquatic herb at KAHO ponds.	I	-	C, lc	-
SOLANACEAE - NIGHTSHADE FAMILY				
Capsicum annuum L. Cayenne pepper Planted at PUHE Visitor Center.	A	-	-	R, p
Capsicum frutescens L. Cayenne pepper Planted at PUHE Visitor Center.	A	-	-	R, p
Datura stramonium L. Jimson weed Reported PUHE 1982; not seen in 1992-94.	A	-	-	?
Lycium sandwicense A. Gray *`Ōhelo kai* Ponds and coastal sites at KAHO.	I	-	O, lc	-
Lycopersicon pimpinellifolium (Jusl.) Mill. Currant tomato Reported PUHE 1977; not seen in 1992-94.	A	-	-	?
Nicotiana glauca R. C. Graham Tree tobacco Reported PUHO before 1986; not seen in 1986 or 1992-94 surveys.	A	?	-	-

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
SOLANACEAE - NIGHTSHADE FAMILY (Continued)				
Nicotiana tabacum L. Tobacco Planted at PUHO; new addition to KAHO flora in 1997, but not found in 1998.	A	R, p	R	-
Solanum americanum Mill. [Syn: *Solanum nigrum* L.] *Pōpolo*, glossy nightshade One plant seen near *Kaloko* Pond in 1994. Reported PUHO 1986; not seen in 1992-94.	I	?	R	-
Solanum lycopersicon L. var. *cerasiforme* (Dunal) Spooner, Anderson & Jansen[2] [Syn: *Lycopersicon esculentum* Mill.] Tomato One plant near *Kaloko* Pond in 1994; also planted at *`Ai`ōpio.*	A	-	R	-
STERCULIACEAE - CACAO FAMILY				
Waltheria indica L. [Syn: *Waltheria americana* L.] *`Uhaloa, hi`aloa*	I	A	C	O
THYMELAEACEAE - `ĀKIA FAMILY				
Wikstroemia pulcherrima Skottsb. *`Ākia* Planted at PUHO Visitor Center.	E	R, p	-	-
Wikstroemia sp. *`Ākia* Planted at PUHE Visitor Center.	E	-	-	R, p
TILIACEAE - LINDEN FAMILY				
Triumfetta semitriloba Jacq. Sacramento bur	A	U	-	U

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
VERBENACEAE - VERBENA FAMILY				
Lantana camara L. Lantana	A	C	C	O
Stachytarpheta jamaicensis (L.) Vahl Jamaica vervain	A	-	R	-
Vitex rotundifolia L. fil. [Syn: *Vitex ovata* Thunb.] *Pōhinahina*, beach vitex Planted at PUHO Visitor Center.	I	U, p	-	-
ZYGOPHYLLACEAE - CREOSOTE BUSH FAMILY				
Tribulus cistoides L. *Nohu* Reported PUHE 1977; not seen in 1992-94.	I	-	R	?
Tribulus terrestris L. Puncture vine	A	C	R	O
UNKNOWN FAMILY				
Unknown species 1 One shrub of unidentified species planted at PUHE Visitor Center.	A	-	-	R, p
Unknown species 2 One tree of unidentified species planted near salt pan at KAHO.	A		R, p	
FLOWERING PLANTS - MONOCOTYLEDONS (LILIOPSIDA)				
AGAVACEAE - AGAVE FAMILY				
Agave attenuata Salm-Dyck Dragon-tree agave Planted at former Superintendent's house at PUHO and near KAHO saltpan.	A	R, p	R, p	-

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
AGAVACEAE - AGAVE FAMILY (Continued)				
Agave sisalana Perrine Sisal Planted at *Pu`uoina Heiau*; new addition to KAHO flora in 1997.	A	-	R, p	-
Cordyline fruticosa (L.) A. Chev. [Syn: *Cordyline terminalis* (L.) Kunth] *Kī, ti* Planted at PUHE and PUHO; addition to KAHO flora in 1997.	P	O, p	R, p	U, p
Pleomele marginata (Lam.) N.E. Br. Money tree Planted at all 3 Parks; addition to KAHO in 1997; removed from PUHO in 1998.	A	R, p	R, p	R, p
Sansevieria trifasiata Prain var. *laurentii* (de Wild.) N.E. Br. Bowstring hemp, snake plant Planted at PUHO former Superintendent's house and at KAHO near *`Ai`ōpio*.	A	R, p	R, p	-
ARACEAE - PHILODENDRON FAMILY				
Colocasia esculenta (L.) Schott *Kalo, taro* Planted at PUHO Visitor Center.	P	U, p	-	-
Epipremnum pinnatum (L.) Engl. *Taro* vine, pothos Planted at PUHO former Superintendent's house; removed in 1998.	A	R, p	-	-
Monstera deliciosa Liebm. Monstera One plant near saltpan at KAHO.	A	-	R, p	-

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
ARECACEAE (PALMAE) - PALM FAMILY				
Cocos nucifera L. *Niu*, coconut	P	C	C, lc	O
Phoenix canariensis Hort. ex Chaubaud Canary Island date palm	A	-	-	R
Phoenix sp. Date palm Few young plants near shore at PUHO.	A	R	R	-
Pritchardia affinis Becc. *Loulu* Planted at PUHE and PUHO.	E	R, p	-	R, p
BROMELIACEAE - BROMELIAD FAMILY				
Ananas comosus (L.) Merr. Pineapple Planted at former Superintendent's house PUHO; removed in 1998. Planted at PUHE Visitor Center and near *Pu`uoina Heiau,* KAHO.	A	R, p	R, p	R, p
CANNACEAE - CANNA FAMILY				
Canna indica L. Indian shot, *ali`i poe* Reported PUHO 1986; not seen in 1992-94.	A	?	-	-
COMMELINACEAE - SPIDERWORT FAMILY				
Commelina benghalensis L. Hairy *honohono*	A	U	U	-
Commelina diffusa N. L. Burm. Dayflower, *honohono*	A	U, lc	-	-

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
COMMELINACEAE - SPIDERWORT FAMILY (Continued)				
Tradescantia spathacea Sw. [Syn: *Rhoeo spathacea* (Sw.) Stearn] Oyster plant Planted at former Superintendent's house PUHO; new addition to KAHO flora in 1997.	A	R, p	R,p	-
Tradescantia zebrina Bosse [Syn: *Zebrina pendula* Schnizl.] Wandering Jew Planted at former Superintendent's house PUHO; removed in 1998.	A	R, p	-	-
CYPERACEAE - SEDGE FAMILY				
Bolboschoenus maritimus (L.) Palla subsp. *paludosus* (A. Nels.) T. Koyama [Syn: *Scirpus maritimus* L. var. *paludosus* (A. Nels.) Kükenth.] *Kaluhā* Sedge of marshes and ponds.	I	-	C	-
Cyperus compressus L. No common name Few small plants near Great Wall of PUHO.	A	U	-	-
Cyperus laevigatus L. *Makaloa* Wetlands and anchialine pools in KAHO and PUHO.	I	C, lc	C, lc	-
Cyperus rotundus L. Nut grass Only in developed area at PUHO.	A	C,lc	-	-
Fimbristylis cymosa R. Br. *Mau`u `aki`aki*	I	C,lc	U	-
Fimbristylis dichotoma (L.) Vahl Tall fringe rush Reported KAHO 1990; not seen in 1992-94.	I	-	?	-

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
CYPERACEAE - SEDGE FAMILY (Continued)				
Fimbristylis hawaiiensis Hillebr. No common name A former candidate endangered species, now species of concern.	E	-	R	-
Kyllinga brevifolia Rottb. [Syn: *Cyperus brevifolius* (Rottb) Hassk.] *Kili`o`opu*	A	U	-	U
Kyllinga nemoralis (J. R. Forster & G. Forster) Dandy ex Hutchinson & Dalziel [Syn: *Cyperus kyllinga* Endl.] *Kili`o`opu*	A	-	-	U
Mariscus javanicus (Houtt.) Merr. & Metcalfe [Syn: *Cyperus javanicus* Houtt.] *`Ahu`awa, `ehu`awa* Present at two sites in KAHO; near ponds at PUHO.	I	C, Ic	R	-
Mariscus meyenianus (Kunth) Nees No common name Reported PUHO before 1986; not seen in 1986 or 1993-94.	A	?	-	-
Pycreus polystachyos (Rottb.) P. Beauv. [Syn: *Cyperus polystachyos* Rottb.] No common name At one site in KAHO.	I	O	R	-
DIOSCOREACEAE - YAM FAMILY				
Dioscorea alata L. *Uhi,* yam Planted at PUHO Visitor Center.	P	R, p	-	-
LILIACEAE - LILY FAMILY				
Aloe vera L. Aloe Planted at all three Parks.	A	O, p	U, p	R, p

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
LILIACEAE - LILY FAMILY (Continued)				
Asparagus densiflorus(Kunth) Jessop Asparagus fern Planted near saltpan at KAHO; addition to flora in 1998.	A	-	R, p	-
Crinum sp. Spider lily Addition to PUHO flora in 1998.	A	R, p	-	-
MUSACEAE - BANANA FAMILY				
Musa sp. *Mai`a*, banana Planted at PUHE Visitor Center; addition to KAHO flora in 1997.	P?	-	R, p	R, p
PANDANACEAE - SCREW PINE FAMILY				
Pandanus tectorius S. Parkinson ex Z *Hala, pūhala* Addition to KAHO flora in 1997.	I	O	R	U
Pandanus sp. *Hala* Cultivar planted at PUHE Visitor Center.	A?	-	-	R, p
POACEAE (GRAMINEAE) - GRASS FAMILY				
Aristida adscensionis L. Sixweeks threeawn Reported PUHE 1977.	A	-	-	?
Axonopus sp. Carpetgrass In lawn at PUHE Visitor Center.	A	-	-	U
Brachiaria mutica (Forssk.) Stapf California grass Reported PUHO 1986; not seen in 1992-94.	A	?	-	-

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
POACEAE - GRASS FAMILY (Continued)				
Cenchrus ciliaris L. Buffelgrass Most common grass at PUHE; possibly eradicated from PUHO.	A	R	U	A
Cenchrus echinatus L. Common sandbur	A	O	-	U
Chloris barbata (L.) Sw. Swollen fingergrass	A	U	U	U
Chloris virgata Sw. Feather fingergrass Reported PUHE 1977; not seen in 1992-94.	A	-	U	?
Cynodon dactylon (L.) Pers. Bermuda grass	A	C, lc	U	U
Cynodon sp. No common name Reported PUHO 1986; not seen in 1992-94.	A	?	-	-
Dactyloctenium aegyptium (L.) Willd. Beach wiregrass Reported PUHE 1982; not seen in 1992-94.	A	U	U	?
Digitaria fuscescens (K. Presl) Henr. Creeping *kukaepua`a*	A	-	-	U
Digitaria insularis (L.) Mez ex Ekman [Syn: *Tricachne insularis* (L.) Nees.] Sourgrass	A	U	-	-
Digitaria setigera Roth *Kūkaepua`a*, itchy crabgrass Addition to KAHO flora in 1997.	I?	-	R	-
Digitaria sp. Crabgrass In lawn at PUHE Visitor Center.	A	O	-	U
Eleusine indica (L.) Gaertn. Wiregrass	A	O	U	U
Eragrostis cilianensis (All.) Link Stinkgrass	A	-	-	U

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
POACEAE - GRASS FAMILY (Continued)				
Eragrostis tenella (L.) P. Beauv. ex Roem. & Schult. Japanese lovegrass	A	O	U	U
Heteropogon contortus (L.) P. Beauv. ex Roem. & Schult. *Pili* Planted near PUHO Visitor Center, also growing wild in Park.	I	U	R	R
Melinis minutiflora P. Beauv. Molasses grass Found at only one site in KAHO.	A	-	R	-
Melinis repens (Willd.) Zizka[3] [Syn: *Rhynchelytrum repens* (Willd.) Hubb.; *Tricholaena rosea* Nees] Natal redtop Most common grass in northern half of PUHO.	A	A	C	U
Panicum fauriei Hitchc. var. *latius* (St. John) Davidse [Syn: *Panicum nubigenum* Kunth] No common name Annual grass reported KAHO 1990; not seen during 1992-94 survey.	E	-	?	-
Panicum maximum Jacq. Guinea grass Most common grass in southern half of PUHO.	A	A	C, Ic	R
Paspalum conjugatum Bergius *Hilo* grass In lawn at PUHE Visitor Center.	A	-	-	U
Paspalum vaginatum Sw. or *Paspalum distichum* L. Seashore paspalum or knotgrass Uncertainty about identity due to lack of fertile material.	A	-	A, Ic	-

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
POACEAE - GRASS FAMILY (Continued)				
Pennisetum setaceum (Forssk.) Chiov. Fountain grass. Reported PUHO 1986; not seen in 1992-94; eradicated from Park? Most abundant grass in KAHO.	A	?	A	C
Saccharum officinarum L. *Kō*, sugar cane. Planted at PUHE and PUHO Visitor Centers.	P	R, p	-	R, p
Setaria verticillata (L.) P. Beauv. Bristly foxtail	A	-	U	R
Sporobolus diander (Retz.) P. Beauv. Indian dropseed. Reported PUHO 1986; not seen in 1992-94.	A	?	-	-
Sporobolus indicus (L.) R. Br. West Indian dropseed. In lawn at PUHE Visitor Center.	A	-	-	U
Sporobolus virginicus (L.) Kunth *`Aki`aki*, beach dropseed	I	-	C, lc	C, lc
Stenotaphrum secundatum (Walter) Kuntze St. Augustine grass. Near Visitor Center in PUHO.	A	C, lc	-	-
Vulpia sp. Fescue. One dry plant seen at PUHE in 1992-94.	A	-	-	R
RUPPICACEAE - DITCHGRASS FAMILY				
Ruppia maritima L. Widgeon grass. In anchialine pools at KAHO.	I	-	R	-

CHECKLIST OF VASCULAR PLANT SPECIES IN
THREE KONA NATIONAL HISTORICAL PARKS

	Status	PUHO	KAHO	PUHE
TACCACEAE - TACCA FAMILY				
Tacca leontopetaloides (L.) Kuntze *Pia*, Polynesian arrowroot Planted at PUHE and PUHO.	P	R, p	-	R, p
ZINGIBERACEAE - GINGER FAMILY				
Curcuma longa L. *ʻŌlena*, turmeric Planted at PUHE and PUHO.	P	R, p	-	R, p

CHECKLIST OF VASCULAR PLANT SPECIES IN THREE KONA NATIONAL HISTORICAL PARKS

SOURCES OF NOMENCLATURE

Primary sources:

Wagner, W. H. Jr. And F. S. Wagner. 1995. Revised tentative checklist of Hawaiian Pteridophytes. Unpublished checklist, Feb. 22, 1995. 10 pp.

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Annotations in checklist:

[1] Wagner, W. L., D. R. Herbst, and S. H. Sohmer. 1989. Contributions to the flora of Hawai`i. II. Begoniaceae-Violaceae and the Monocotyledons. Bishop Museum Occasional Papers 29: 88-130.

[2] Wagner, W. L., R. K. Shannon, and D. R. Herbst. 1997. Contributions to the flora of Hawai`i. VI. Records of the Hawaii Biological Survey for 1996. Part 1: Articles. N. L. Evenhuis and S. E. Miller (eds.). Bishop Museum Occasional Papers 48: 51-65.

[3] Herbst, D. R. and W. D. Clayton. 1998. Notes on the grasses of Hawai`i: New records, corrections, and name changes. Records of the Hawaii Biological Survey for 1997. Part 1: Articles. N. L. Evenhuis and S. E. Miller (eds.). Bishop Museum Occasional Papers 55: 17-38.

CHECKLIST OF VASCULAR PLANT SPECIES IN THREE KONA NATIONAL HISTORICAL PARKS

SUMMARY (For Three Parks Combined)

Plant Group and Status	Number of Species*	(% of total in group)
Ferns and Fern Allies	6	
Endemic	1	(17%)
Indigenous	2	(33%)
Alien	3	(50%)
Flowering Plants - Dicotyledons	166	
Endemic	11	(7%)
Indigenous	21	(13%)
Polynesian Introduction	10	(6%)
Alien	124	(75%)
Flowering Plants - Monocotyledons	65	
Endemic	2	(3%)
Indigenous	10	(15%)
Polynesian Introduction	8	(12%)
Alien	45	(69%)
Total- Vascular Plants	237	
Endemic	14	(6%)
Indigenous	33	(14%)
Polynesian Introduction	18	(8%)
Alien	172	(73%)

* Does not include those species on previous checklists that were not seen in 1992-94 surveys. Some of the species on previous checklists have probably disappeared, but others may persist and remain part of the Parks' flora.

Appendix C

THE POLLEN RECORD AT `AIMAKAPĀ FISHPOND

Christine J. Douglas and Sara C. Hotchkiss

The Pollen Record at 'Aimakapa fishpond

Christine J. Douglas
Sara C. Hotchkiss

Introduction

This project was designed to use the techniques of pollen analysis to investigate the vegetation history of the area surrounding Kaloko Fish Pond, for the use of the Park Management Team as they restore the area to a more natural state. In the course of the project, we expanded the work to include 'Aimakapa Fish Pond as well. Adding 'Aimakapa proved to be fortuitous, because it provided a more useful sedimentary record than Kaloko.

Pollen analysis is a fairly blunt instrument for reconstructing vegetation, because the spatial and temporal resolution are limited and the taxonomic resolution is not always as detailed as we would like. However, it is possible to identify many Hawaiian species and genera from their pollen or spores, and some taxa introduced by Polynesians or by Europeans can provide useful time markers. In addition, we have a library of surface pollen assemblages that can be used to interpret fossil pollen assemblages by analogy with modern vegetation.

Sediments collecting in sedimentary basins contain pollen that has been transported from vegetation surrounding the site. The larger the sedimentary basin, the larger the source area for the pollen. While exact pollen source areas are unknown, a model of pollen dispersal for northern temperate regions suggests that Kaloko and Aimakapa are likely to collect pollen from a large radius--at least 0.5 km, and probably larger (Sugita 1993).

To interpret stratigraphic sequences as time series, it is necessary to assume that the sediments were deposited sequentially, with the youngest sediments at the top. This assumption is not necessarily met in fishponds, since they have been used extensively by humans for a long time. In addition, the sediments we collected from Kaloko and 'Aimakapa are very soft and therefore easily disturbed.

In this project we collected several cores of sediment from both Kaloko and 'Aimakapa fishponds, and rather than establishing detailed chronology and stratigraphy, we committed all of the remaining resources to analysis of the pollen. Here we provide the results of the pollen analysis, and we suggest avenues for future research that could be done using the sediments we have already collected.

Methods

Coring. We used a Livingstone piston corer and plastic tubes with pistons or stoppers to collect sediment cores from a floating platform. We were able to collect all available sediment, reaching underlying basalt at the end of each drive.

Pollen analysis. Pollen sample preparation followed a modified version of Faegri and Iversen's (1989) method, involving disaggregation of the sediment using KOH, sieving to remove large particles, removal of carbonates using HCl, removal of silicates using HF, removal of some organic matter using acetic anhydride and concentrated sulfuric acid, dehydration in alcohol, and mounting in silicone oil. Slides were mounted under free-moving cover slips to allow rotation of individual grains for identification. Samples were counted at 400x magnification (numerical aperture 0.85), with occasional identifications made at 1000x, under a water-immersion lens (numerical aperture 1.20). Taxonomic references included Selling (1946, 1947) and reference collections maintained by E.J. Cushing, M.B. Davis, and S.C. Hotchkiss at the University of Minnesota. Nomenclature follows Wagner, Herbst and Sohmer (1990) for flowering plants, and Wagner and Wagner (personal communication 1992) for pteridophytes. Pollen percentage calculations are based on a sum of all pollen and spore types, excluding Cyperaceae and *Batis maritima*.

Comparison of pollen assemblages. Modern analogs to fossil pollen assemblages were identified using a signal-to-noise ratio measure of dissimilarity called the squared chord distance:

$$d_{ij} = \sum_{k=1}^{n} \left(\sqrt{P_{ik}} - \sqrt{P_{jk}} \right)^2$$

where d_{ij} is the squared chord distance between sample i and sample j, p_{ik} is the proportion of pollen type k in sample i, p_{jk} is the proportion of pollen type k in sample j, and n is the number of pollen types (Prentice 1980; Overpeck *et al.* 1985).

Results and Discussion

Eight cores were collected from 'Aimakapa and Kaloko fishponds (Figures 1 and 2). In general, the sediment at 'Aimakapa was deeper and apparently older than that of Kaloko. The longest core from Kaloko was taken at the north end of the pond and measured 28 cm in length. The sediment at the bottom of this core contained high percentages of *Batis maritima* pollen, indicating that even the oldest sediments at Kaloko originate from the period after European settlement. For this reason, no further pollen analysis was performed at Kaloko.

In contrast, the longest core from 'Aimakapa was 73 cm long. The bottom of this core was devoid of any exotic pollen types, indicating that it was deposited before European settlement. For this reason, we chose to analyze this core in detail. Although we have no radiocarbon dates for the core, it is probably reasonable to assume that the core is not more than 1000 years old. The top 37 cm represent about 200 years of sedimentation. Although deeper sediments are more compact, low pollen concentrations suggest sedimentation rates were high. The bottom 35 cm probably represents a relatively short period of time. The very surface of the core contained almost no pollen, thus the most recent sample analyzed is 12 cm below the sediment surface. Between 12 and 73 cm, fourteen samples were analyzed. The results of this analysis are presented in Figure 3. Plant taxa included in each pollen type are given in Table 1.

The pollen record from 'Aimakapa can be divided into two distinct zones. There are no European-introduced pollen taxa below 37cm; the pollen record below this level represents the vegetation surrounding 'Aimakapa during the time before European arrival, when Polynesians lived in the area. Cyperaceae, *Pritchardia*, and Chenopodiaceae-Amaranthaceae pollen dominate this zone. Although Cyperaceae pollen can be positively identified only to family, several different species were probably present given the wide variety in the morphology of the Cyperaceae grains observed. Cyperaceae accounts for most of the pollen throughout much of the core because it grows in the pond itself, and because it produces a lot of pollen. For this reason, it can mask weaker pollen signals and was therefore excluded from the sum. *Pritchardia* grains were found throughout most of the core, but they are most abundant in the pre-European zone, reaching a maximum of 25% around 65 cm. Like Cyperaceae, Chenopodiaceae-Amaranthaceae is a pollen type with low taxonomic resolution. However, before Europeans introduced many exotic taxa in this group, *Chenopodium oahuense* could be distinguished from the few Hawaiian members of this pollen taxon. Most of the Chenopodiaceae-Amaranthaceae grains seen in this zone were consistent with the morphology of *Chenopodium oahuense*.

Other taxa present at 'Aimakapa during this period include *Chamaesyce*-type, *Cheirodendron trigynum*, other members of the Araliaceae, *Coprosma*, *Dodonaea*, *Myrsine*, *Rubus*, cf. *Tacca*, cf. *Cocos*, and undifferentiated monolete fern spores. The *Chamaesyce* pollen type includes species of *Chamaesyce* and *Euphorbia*. Although most of the *Chamaesyce*-type grains observed were of one kind, several seemingly distinct grains were observed throughout, suggesting that more than one species may have been present. *Cheirodendron trigynum* was the only type of Araliaceae identified to species, although several grains that resembled reference material of *Reynoldsia* were observed at the bottom of the core. *Cf. Tacca* and *cf. Cocos* were the only Polynesian introductions that were observed in the core, but identification is uncertain at this stage. These pollen types are comprised of monosulcate grains that are distinct from

Pritchardia, and are similar to reference material from *Tacca* and *Cocos*. However, neither the literature nor the few reference samples available allow us to make a positive identification of these two taxa. Although several Polynesian cultivars are included in the Convolvulaceae and Malvaceae pollen types, the observed grains in these taxa were compared with reference material of cultivars and determined to be different.

We compared each fossil pollen assemblage with a library of 108 surface pollen assemblages in a wide range of vegetation types on the Island of Hawai'i. A study comparing modern pollen assemblages with vegetation data showed that pollen assemblages that differ by a squared chord distance of < 0.5 tend to come from similar vegetation types (Hotchkiss and Douglas, *in preparation*). When the pollen record at 'Aimakapa was compared with a library of surface samples using the method explained above, the assemblage from the pre-European zone appeared most similar to a sample collected from a small *Acacia koaia* preserve on leeward Kohala Mountain and two samples from 9000-10,000 feet elevation on Mauna Kea above Pu'u La'au (Figure 4). Note that only two of the fossil assemblages have a squared chord distance < 0.5. Because there are few dry-side coastal surface samples in the library, the resolution of this technique is low, but it provides a rough indication of what the site might have looked like before Europeans arrived. The post-European pollen assemblages from this record had no analogs among the surface samples in the library.

An abrupt transition occurs around 37 cm when *Batis maritima* arrives at the site and begins to increase rapidly. Like Cyperaceae, *Batis maritima* grows in the water and produces a lot of pollen, and was thus excluded from the sum. Several other exotic types also appear at this time, and many of the native types from the previous zone decrease markedly. The transition marks arrival of Europeans and exotic plants to the island about 200 years ago. *Batis maritima* expanded rapidly, first appearing in the core at 37 cm and nearly dominating the assemblage at 32 cm. *Batis maritima* continues to increase, reaching maximum proportions at 23 cm. *Prosopis* arrives along with *Batis maritima*, but remains at low percentages for some time. However, *Prosopis* eventually increases dramatically to dominate the assemblage at the top of the core. At this time *Batis maritima* declines.

While *Batis maritima* and *Prosopis* increase, many native taxa from the pre-European zone decline. *Chamaesyce*-type disappears almost immediately. Very small percentages at the top of the core could originate from the two naturalized species present near the site today. Chenopodiaceae declines more slowly, remaining at about 15% until the top sample, where it is absent. Cyperaceae declines but continues to be very important until the top sample. Though it declines, *Pritchardia* also remains important until the top sample where it too is absent. Other taxa that decline after European arrival are *Acacia koa, Coprosma,* Malvaceae, *Metrosideros-type,* and *Rubus*. As these native types

decline, several new types increase. *Casaurina*, *Plantago*, *Rumex*, Poaceae, and *Cibotium* become more common after European arrival.

In summary, the pollen record at 'Aimakapa shows that the vegetation surrounding the pond experienced an abrubt change after Europeans arrived on the island. Native sedges, palms and chenopods declined, as pickleweed, grass, and kiawe began to dominate the assemblage. Pollen analysis is a useful tool for studying such dramatic shifts in vegetation. However, the near absence of taxa associated with Polynesian plant cultivation suggests that this technique may not be sensitive enough to register the effects of local cultivation. But the presence of cultivars are not the only possible evidence of human settlement. Polynesians may have altered the native assemblage, but because this core is probably not old enough to record a pre-Polynesian assemblage, we cannot make this kind of comparison.

Future Work

Several properties of the 'Aimakapa core suggest possibilities for future work. When the core was extruded, it was noted that the bottom 30 cm contained thousands of macroscopic black particles that were later identified as charcoal. These particles were more frequent below 40 cm—the pre-European period of the core. This suggests that some of the abundant charcoal in this core may originate from Polynesian land use. During pollen analysis, it was noted that many samples contained large amounts of microscopic charcoal. A quantitative analysis of either macroscopic or microscopic charcoal may corroborate the anecdotal observation that fire appears to have been more common at this site prior to European settlement.

When sediments were sieved during pollen extraction, many Cyperaceae seeds were found below 40 cm; several seeds were also found above this level. Because we cannot distinguish the pollen of different taxa in this family, pollen analysis can not tell us about the changing abundance and distribution of Cyperaceae species at the pond over time. However, if Cyperaceae seeds can be identified to genus or species, much of this information could be gained from an analysis of the many seeds preserved in the sediment.

At this point, it is not clear how old the sediments at 'Aimakapa are. We know that they extend beyond European settlement into the Polynesian period. However, we do not know how much of this period they record, or if they might record vegetation from the time prior to Polynesian settlement. The abundance of charcoal and seeds in this core provide many macrofossils for carbon dating. One or two radiocarbon dates would aid in the interpretation of the fossil pollen record.

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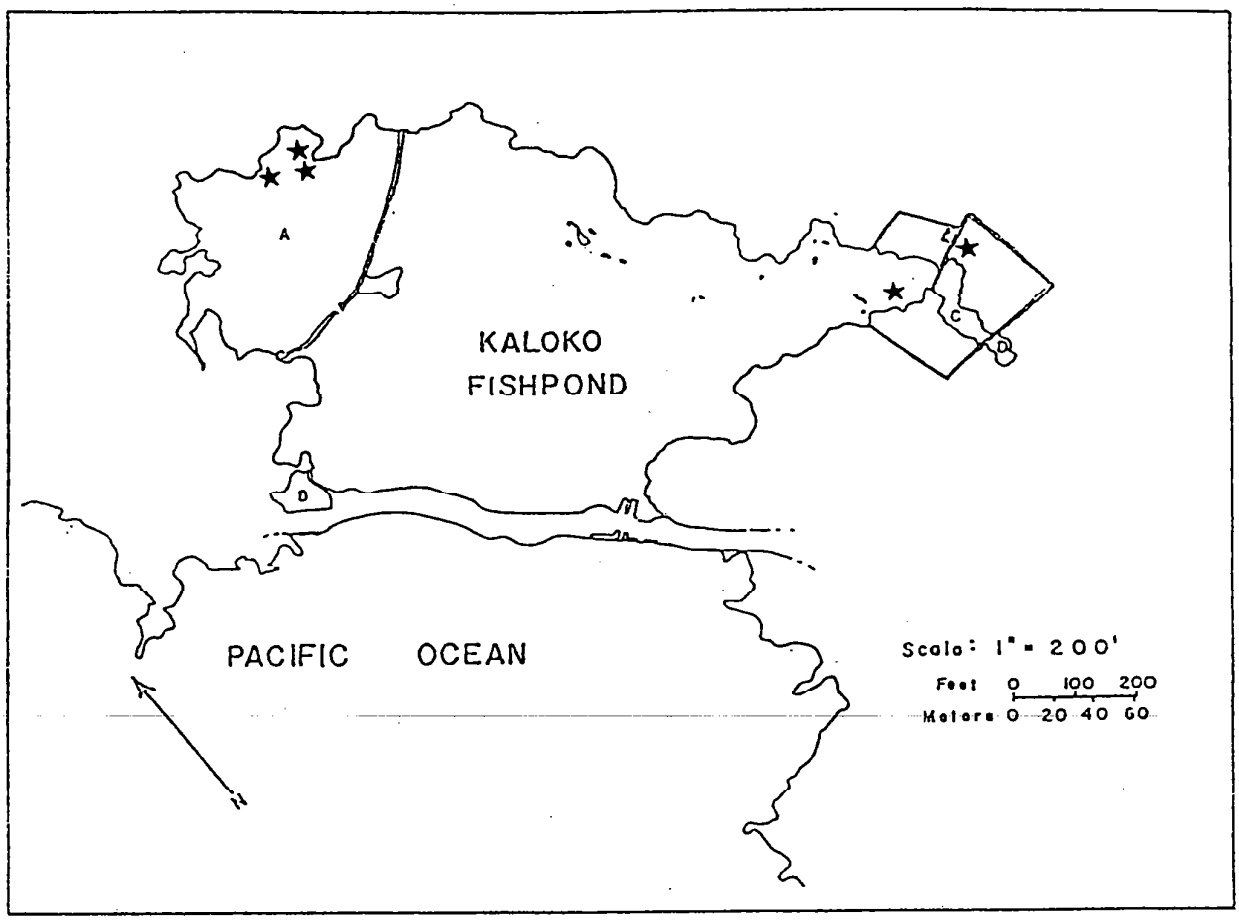

Figure 1. Map of Kaloko fishpond. Stars indicate the locations of five sediment cores taken during the course of this project.

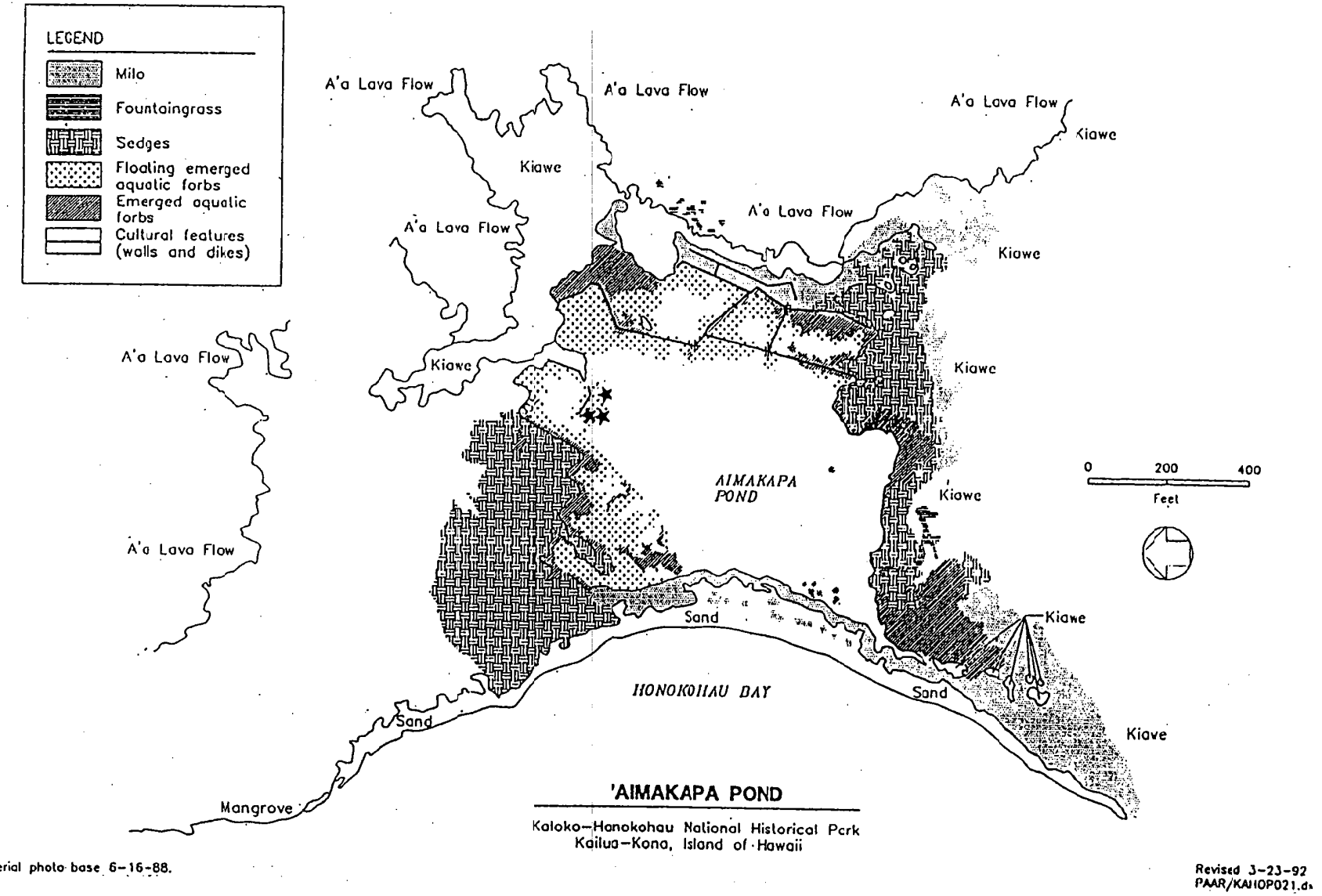

Figure 2. Map of 'Aimakapa fishpond. Stars indicate locations of three sediment cores taken during the course of this project.

'Aimakapa fishpond
Analyst: Christine Douglas
6/98

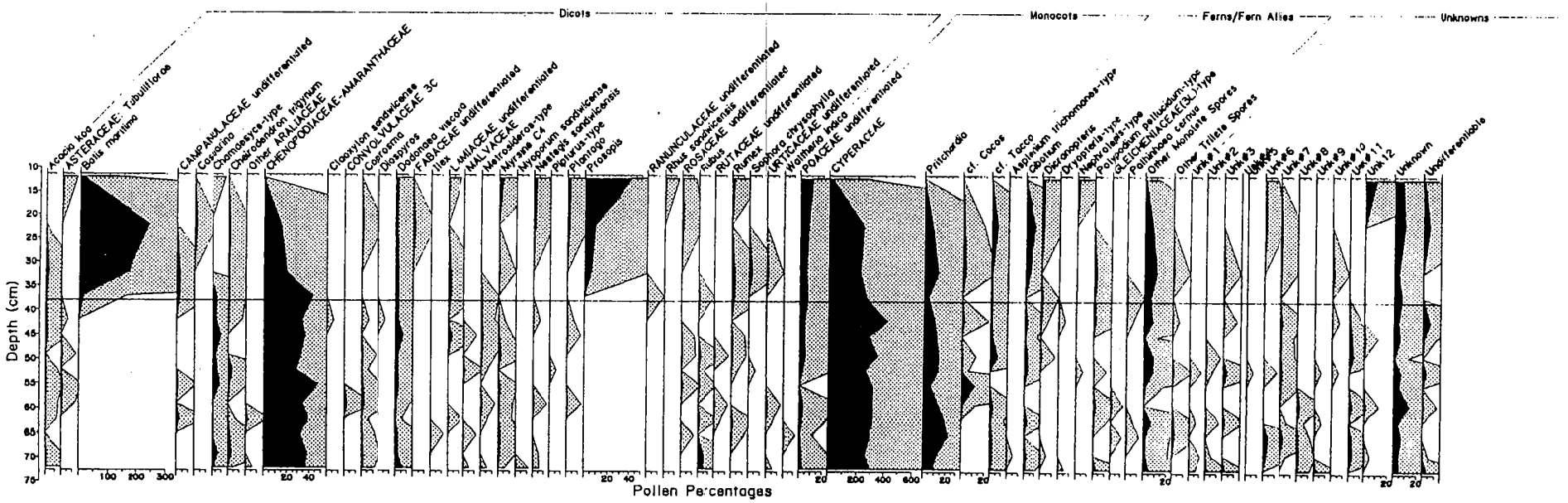

Figure 3. Pollen diagram from 'Aimakapa fishpond

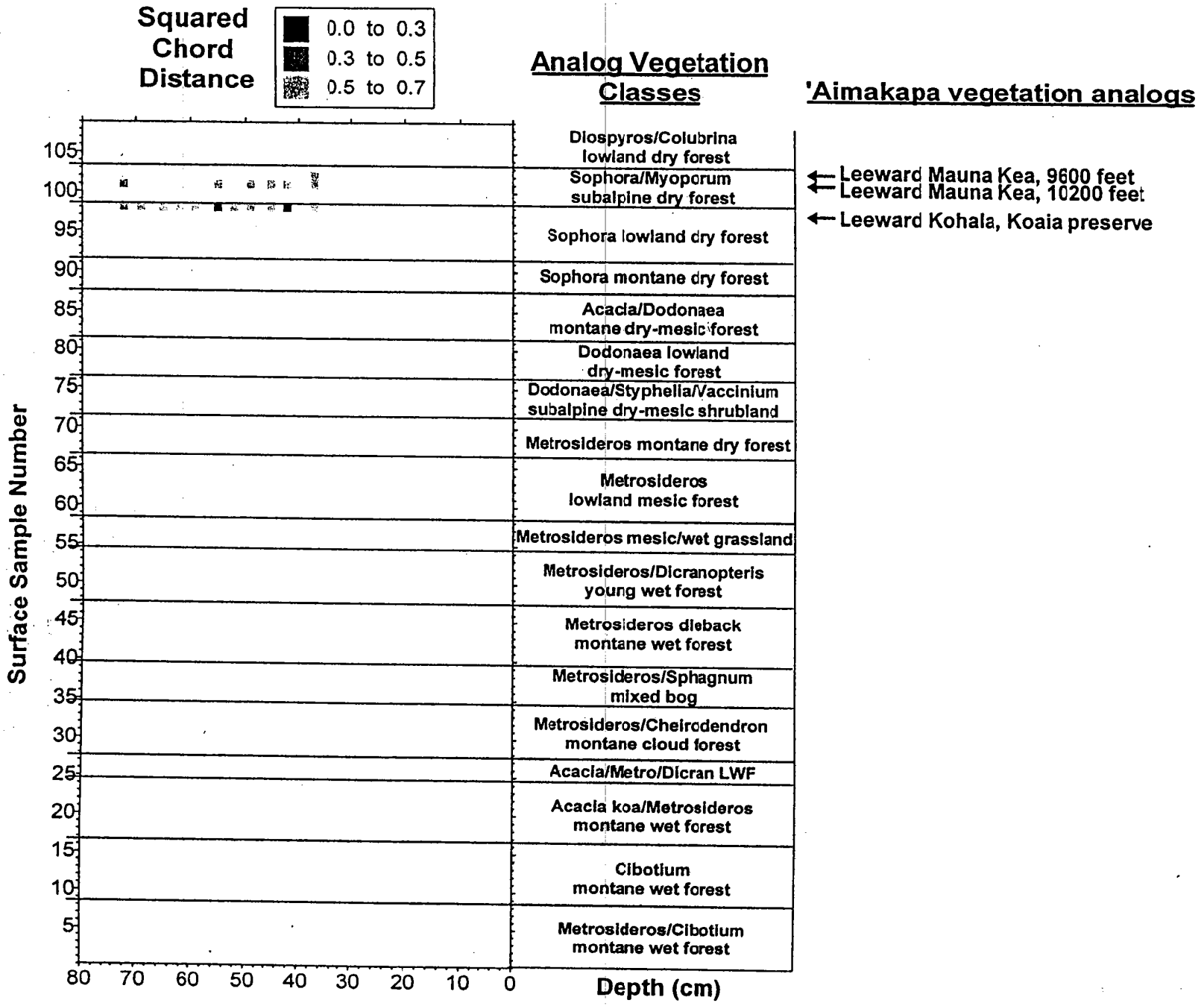

Figure 4. Modern vegetation analogs for fossil pollen assemblages at 'Aimakapa

Table 1. Pollen types found at 'Aimakapa

POLLEN TYPE *and component species*	FAMILY	PROVE-NANCE	POLLEN CLASS
DICOTS			
Rhus sandwicensis	**ANACARDIACEAE**		**C3P3**
Rhus sandwicensis A. Gray	ANACARDIACEAE	E	C3P3
Ilex	**AQUIFOLIACEAE**		**C3P3**
Ilex anomala Hook. & Arnott	AQUIFOLIACEAE	I	C3P3
Ilex aquifolium L.	AQUIFOLIACEAE	N	C3(P3)
Ilex paraguariensis St. Hil.	AQUIFOLIACEAE	N	
Other ARALIACEAE	**ARALIACEAE**		**C3P3**
all members of family except *Cheirodendron trigynum*	ARALIACEAE	N	
Cheirodendron trigynum	**ARALIACEAE**		**C3P3(4)**
Cheirodendron trigynum (Gaud.) A. Heller	ARALIACEAE	E	C3P3(4)
ASTERACEAE: Tubuliflorae	**ASTERACEAE**		**C3P3**
Adenostemma lavenia (L.) Kuntze	ASTERACEAE	I	C3P3
Argyroxiphium caliginis C. Forbes	ASTERACEAE	EG	C3P3
Argyroxiphium grayanum (Hillebr.) Degener	ASTERACEAE	EG	C3P3
Argyroxiphium kauense (Rock & M. Neal) Degener & I. Degener	ASTERACEAE	EG	C3P3
Argyroxiphium sandwicense DC	ASTERACEAE	EG	C3P3
Argyroxiphium virescens Hillebr.	ASTERACEAE	EG	C3P3
Bidens amplectans Sherff	ASTERACEAE	E	C3P3
Bidens asymmetrica (H. Lév.) Sherff	ASTERACEAE	E	C3P3
Bidens campylotheca Schultz-Bip.	ASTERACEAE	E	C3P3
Bidens cervicata Sherff	ASTERACEAE	E	C3P3
Bidens conjuncta Sherff	ASTERACEAE	E	C3P3
Bidens cosmoides (A. Gray) Sherff	ASTERACEAE	E	C3P3
Bidens forbesii Sherff	ASTERACEAE	E	C3P3
Bidens hawaiiensis A. Gray	ASTERACEAE	E	C3P3
Bidens hillebrandiana (Drake) Degener	ASTERACEAE	E	C3P3
Bidens macrocarpa (A. Gray) Sherff	ASTERACEAE	E	C3P3
Bidens mauiensis (A. Gray) Sherff	ASTERACEAE	E	C3P3
Bidens menziesii (A. Gray) Sherff	ASTERACEAE	E	C3P3
Bidens menziesii (A. Gray) Sherff subsp. *filiformis*	ASTERACEAE	E	C3P3
Bidens micrantha Gaud.	ASTERACEAE	E	C3P3
Bidens molokaiensis (Hillebr.) Sherff	ASTERACEAE	E	C3P3
Bidens populifolia Sherff	ASTERACEAE	E	C3P3
Bidens sandvicensis Less.	ASTERACEAE	E	C3P3
Bidens torta Sherff	ASTERACEAE	E	C3P3
Bidens valida Sherff	ASTERACEAE	E	C3P3
Bidens wiebkei Sherff	ASTERACEAE	E	C3P3
Dubautia arborea (A. Gray) D. Keck	ASTERACEAE	EG	C3P3
Dubautia ciliolata (DC) D. Keck	ASTERACEAE	EG	C3P3
Dubautia ciliolata (DC) D. Keck ssp. *glutinosa*	ASTERACEAE	EG	C3P3
Dubautia demissifolia (Sherff) D. Keck	ASTERACEAE	EG	C3P3
Dubautia dolosa (Degener & Sherff) G. Carr	ASTERACEAE	EG	C3P3

POLLEN TYPE *and component species*	FAMILY	PROVE-NANCE	POLLEN CLASS
Dubautia herbstobatae G. Carr	ASTERACEAE	EG	C3P3
Dubautia imbricata St. John & G. Carr	ASTERACEAE	EG	C3P3
Dubautia knudsenii Hillebr.	ASTERACEAE	EG	C3P3
Dubautia laevigata A. Gray	ASTERACEAE	EG	C3P3
Dubautia latifolia (A. Gray) D. Keck	ASTERACEAE	EG	C3P3
Dubautia laxa Hook. & Arnott	ASTERACEAE	EG	C3P3
Dubautia linearis (Gaud.) D. Keck	ASTERACEAE	EG	C3P3
Dubautia menziesii(A. Gray) D. Keck	ASTERACEAE	EG	C3P3
Dubautia microcephala Skottsb.	ASTERACEAE	EG	C3P3
Dubautia paleata A. Gray	ASTERACEAE	EG	C3P3
Dubautia pauciflorula St. John & G. Carr	ASTERACEAE	EG	C3P3
Dubautia plantaginea Gaud.	ASTERACEAE	EG	C3P3
Dubautia platyphylla (A. Gray) D. Keck	ASTERACEAE	EG	C3P3
Dubautia raillardioides Hillebr.	ASTERACEAE	EG	C3P3
Dubautia reticulata (Sherff) D. Keck	ASTERACEAE	EG	C3P3
Dubautia scabra (DC) D. Keck	ASTERACEAE	EG	C3P3
Dubautia scabra (DC) D. Keck ssp. *scabra*	ASTERACEAE	EG	C3P3
Dubautia sherffiana Fosb.	ASTERACEAE	EG	C3P3
Dubautia waialealae Rock	ASTERACEAE	EG	C3P3
Dubautia ciliolata (DC) D. Keck x *scabra* (DC) D. Keck	ASTERACEAE	EG	C3P3
Dubautia x *vafra*	ASTERACEAE	EG	C3P3
Gnaphalium sandwicensium Gaud.	ASTERACEAE	E	C3P3
Lagenifera erici C. Forbes	ASTERACEAE	E	C3P3
Lagenifera helenae C. Forbes & Lydgate	ASTERACEAE	E	C3P3
Lagenifera maviensis H. Mann	ASTERACEAE	E	C3P3
Lipochaeta bryanii Sherff	ASTERACEAE	EG	C3P3
Lipochaeta connata (Gaud.) DC	ASTERACEAE	EG	C3P3
Lipochaeta degeneri Sherff	ASTERACEAE	EG	C3P3
Lipochaeta faurei H. Lév.	ASTERACEAE	EG	C3P3
Lipochaeta heterophylla A. Gray	ASTERACEAE	EG	C3P3
Lipochaeta integrifolia (Nutt.) A. Gray	ASTERACEAE	EG	C3P3
Lipochaeta kamolensis Degener & Sherff	ASTERACEAE	EG	C3P3
Lipochaeta lavarum (Gaud.) DC	ASTERACEAE	EG	C3P3
Lipochaeta lobata (Gaud.) DC	ASTERACEAE	EG	C3P3
Lipochaeta micrantha (Nutt.) A. Gray	ASTERACEAE	EG	C3P3
Lipochaeta ovata Gardner	ASTERACEAE	EG	C3P3
Lipochaeta perdita Sherff	ASTERACEAE	EG	C3P3
Lipochaeta remyi A. Gray	ASTERACEAE	EG	C3P3
Lipochaeta rockii Sherff	ASTERACEAE	EG	C3P3
Lipochaeta subcordata A. Gray	ASTERACEAE	EG	C3P3
Lipochaeta succulenta (Hook. & Arnott) DC	ASTERACEAE	EG	C3P3
Lipochaeta tenuifolia A. Gray	ASTERACEAE	EG	C3P3
Lipochaeta tenuis Degener & Sherff	ASTERACEAE	EG	C3P3
Lipochaeta venosa Sherff	ASTERACEAE	EG	C3P3
Lipochaeta waimeaensis St. John	ASTERACEAE	EG	C3P3

POLLEN TYPE *and component species*	FAMILY	PROVE-NANCE	POLLEN CLASS
Tetramolopium arenarium (A. Gray) Hillebr.	ASTERACEAE	E	C3P3
Tetramolopium capillare (Gaud.) St. John	ASTERACEAE	E	C3P3
Tetramolopium consanguineum (A. Gray) Hillebr.	ASTERACEAE	E	C3P3
Tetramolopium conyzoides (A. Gray) Hillebr.	ASTERACEAE	E	C3P3
Tetramolopium filiforme Sherff	ASTERACEAE	E	C3P3
Tetramolopium humile (A. Gray) Hillebr.	ASTERACEAE	E	C3P3
Tetramolopium lepidotum (Less.) Sherff	ASTERACEAE	E	C3P3
Tetramolopium remyi (A. Gray) Hillebr.	ASTERACEAE	E	C3P3
Tetramolopium rockii Sherff	ASTERACEAE	E	C3P3
Tetramolopium sylvae Lowrey	ASTERACEAE	I	C3P3
Tetramolopium tenerrimum (Less.) Nees	ASTERACEAE	E	C3P3
Wilkesia gymnoxiphium A. Gray	ASTERACEAE	EG	C3P3
Wilkesia hobdyi St. John	ASTERACEAE	EG	C3P3
Acanthospermum australe (Loefl.) Kuntze	ASTERACEAE	N	C3P3
Acanthospermum hispidum DC	ASTERACEAE	N	C3P3
Achillea millefolium L.	ASTERACEAE	N	C3P3
Ageratina adenophora (Spreng.) R. King & H. Robinson	ASTERACEAE	N	C3P3
Ageratina riparia (Regel) R. King & H. Robinson	ASTERACEAE	N	C3P3
Ageratum conyzoides L.	ASTERACEAE	N	C3P3
Ageratum houstonianum Mill.	ASTERACEAE	N	C3P3
Ambrosia artemesiifolia L.	ASTERACEAE	N	C3P3
Anthemis cotula L.	ASTERACEAE	N	C3P3
Arcticum lappa L.	ASTERACEAE	N	C3P3
Artemisia vulgaris L.	ASTERACEAE	N	C3P3
Aster subulatus Michx.	ASTERACEAE	N	C3P3
Baltimora recta L.	ASTERACEAE	N	C3P3
Bellis perennis L.	ASTERACEAE	N	C3P3
Bidens alba (L.) DC	ASTERACEAE	N	C3P3
Bidens cynapiifolia Kunth	ASTERACEAE	N	C3P3
Bidens gardneri Baker	ASTERACEAE	N	C3P3
Bidens pilosa L.	ASTERACEAE	N	C3P3
Blumea laciniata (Roxb.) DC	ASTERACEAE	N	C3P3
Blumea sessiflora Decne.	ASTERACEAE	N	C3P3
Calyptocarpus vialis Less.	ASTERACEAE	N	C3P3
Carduus pycnocephalus L.	ASTERACEAE	N	C3P3
Centaurea melitensis L.	ASTERACEAE	N	C3P3
Centaurea cyanus L.	ASTERACEAE	N	C3P3
Chrysanthemum leucanthemum L.	ASTERACEAE	N	C3P3
Chrysanthemum frutescens L.	ASTERACEAE	N	C3P3
Chrysanthemum maximum Ram.	ASTERACEAE	N	C3P3
Cirsium vulgare (Savi) Ten.	ASTERACEAE	N	C3P3
Conyza bonariensis (L.) Cronq.	ASTERACEAE	N	C3P3
Coreopsis lanceolata L.	ASTERACEAE	N	C3P3
Cosmos bipinnatus Cav.	ASTERACEAE	N	C3P3
Cotula australis (Sieber ex Spreng.) J.D. Hook.	ASTERACEAE	N	C3P3

POLLEN TYPE *and component species*	FAMILY	PROVE-NANCE	POLLEN CLASS
Crassocephalum crepidioides (Benth.) S. Moore	ASTERACEAE	N	C3P3
Dahlia excelsa Benth.	ASTERACEAE	N	C3P3
Dahlia pinnata Cav.	ASTERACEAE	N	C3P3
Dahlia variabilis	ASTERACEAE	N	C3P3
Eclipta alba (L.) Hassk.	ASTERACEAE	N	C3P3
Elephantopus mollis Kunth	ASTERACEAE	N	C3P3
Elephantopus spicatus Juss. ex Aubl.	ASTERACEAE	N	C3P3
Emilia coccinea (Sims) G. Don	ASTERACEAE	N	C3P3
Emilia fosbergii Nicolson	ASTERACEAE	N	C3P3
Emilia sonchifolia (L.) DC	ASTERACEAE	N	C3P3
Encelia farinosa A. Gray	ASTERACEAE	N	C3P3
Erechtites heiracifolia (L.) Raf. ex DC	ASTERACEAE	N	C3P3
Erechtites valerianifolia (Wolf) DC	ASTERACEAE	N	C3P3
Erigeron bellioides DC	ASTERACEAE	N	C3P3
Erigeron karvinskianus DC	ASTERACEAE	N	C3P3
Filago gallica L.	ASTERACEAE	N	C3P3
Fitchia speciosa Cheeseman	ASTERACEAE	N	C3P3
Flaveria trinervia (Spreng.) C. Mohr	ASTERACEAE	N	C3P3
Gaillardia pulchella Foug.	ASTERACEAE	N	C3P3
Galinsoga parviflora Cav.	ASTERACEAE	N	C3P3
Gallinsoga quadriculata Ruiz & Pav.	ASTERACEAE	N	C3P3
Gerbera jamesoni Bolus	ASTERACEAE	N	C3P3
Gnaphalium japonicum Thunb.	ASTERACEAE	N	C3P3
Gnaphalium purpureum L.	ASTERACEAE	N	C3P3
Helianthus annuus L.	ASTERACEAE	N	C3P3
Helichrysum foetidum (L.) Cass.	ASTERACEAE	N	C3P3
Helichrysum bracteatum (Vent.) Andr.	ASTERACEAE	N	C3P3
Heterotheca grandiflora Nutt.	ASTERACEAE	N	C3P3
Madia sativa Molina	ASTERACEAE	N	C3P3
Montanoa hibiscifolia Benth.	ASTERACEAE	N	C3P3
Osteospermum calendulaceum L. fil.	ASTERACEAE	N	C3P3
Palafoxia callosa (Nutt.) Torr. & A. Gray	ASTERACEAE	N	C3P3
Parthenium hysterophorus L.	ASTERACEAE	N	C3P3
Pectis linifolia L.	ASTERACEAE	N	C3P3
Petasites japonicus (Siebold & Zucc.) Maxim.	ASTERACEAE	N	C3P3
Pluchea x *fosbergii* Cooperr. & Galang	ASTERACEAE	N	C3P3
Pluchea indica (L.) Less.	ASTERACEAE	N	C3P3
Pluchea symphitifolia (Mill.) Gillis	ASTERACEAE	N	C3P3
Senecio mikanioides Otto ex Walp.	ASTERACEAE	N	C3P3
Senecio sylvaticus L.	ASTERACEAE	N	C3P3
Senecio vulgaris L.	ASTERACEAE	N	C3P3
Sigesbechia orientalis L.	ASTERACEAE	N	C3P3
Solidago canadensis L.	ASTERACEAE	N	C3P3
Stokesia laevis (Hill) Greene	ASTERACEAE	N	C3P3
Synedrella nodiflora (L.) Gaertn.	ASTERACEAE	N	C3P3
Tagetes minuta L.	ASTERACEAE	N	C3P3

POLLEN TYPE *and component species*	FAMILY	PROVE-NANCE	POLLEN CLASS
Tagetes erecta L.	ASTERACEAE	N	C3P3
Tagetes patula L.	ASTERACEAE	N	C3P3
Tithonia diversifolia (Hemsl.) A. Gray	ASTERACEAE	N	C3P3
Tridax procumbens L.	ASTERACEAE	N	C3P3
Verbesina encelioides (Cav.) Benth. & Hook.	ASTERACEAE	N	C3P3
Veronia cinerea (L.) Less.	ASTERACEAE	N	C3P3
Wedelia trilobata (L.) Hitchc.	ASTERACEAE	N	C3P3
Xanthium strumarium L.	ASTERACEAE	N	C3P3
Zinnia elegans Jacq.	ASTERACEAE	N	C3P3
Zinnia palmeri A. Gray	ASTERACEAE	N	C3P3
Zinnia peruviana (L.) L.	ASTERACEAE	N	C3P3
Batis	**BATACEAE**		**CPstp** C4P4(C3P3)
Batis maritima L.	BATACEAE	N	
CAMPANULACEAE	**CAMPANULACEAE**		**C3P3**
all members of family	CAMPANULACEAE	N	
Casuarina	**CASUARINACEAE**		**P3**
Casuarina equisetifolia L.	CASUARINACEAE	N	
Casuarina glauca Siebold ex Spreng.	CASUARINACEAE	N	
CHENOPODIACEAE-AMARANTHACEAE	**CHENOPODIACEAE, AMARANTHACEAE**		**Pperi**
Amaranthus brownii Christoph. & Caum	AMARANTHACEAE	E	
Aerva sericea Moq.	AMARANTHACEAE	PI?	
Achyranthes aspera L.	AMARANTHACEAE	N	
Alternathera brasiliana (L.) Kuntze	AMARANTHACEAE	N	
Alternathera caracasana Kunth	AMARANTHACEAE	N	
Alternathera pungens Kunth	AMARANTHACEAE	N	
Alternathera sessilis (L.) DC	AMARANTHACEAE	N	
Alternathera tenella Colla	AMARANTHACEAE	N	
Amaranthus dubius Mart. ex Thell.	AMARANTHACEAE	N	
Amaranthus hybridus L.	AMARANTHACEAE	N	
Amaranthus lividus L.	AMARANTHACEAE	N	
Amaranthus spinosus L.	AMARANTHACEAE	N	P4
Amaranthus tricolor L.	AMARANTHACEAE	N	
Amaranthus viridis L.	AMARANTHACEAE	N	
Gomphrena celosioides Mart.	AMARANTHACEAE	N	
Gomphrena globosa L.	AMARANTHACEAE	N	
Atriplex eardleyae Aellen	CHENOPODIACEAE	N	
Atriplex lentiformis (Torr.) S. Wats.	CHENOPODIACEAE	N	
Atriplex semibaccata R. Br.	CHENOPODIACEAE	N	
Atriplex suberecta Verd.	CHENOPODIACEAE	N	
Bassia hyssopifolia (Pall.) Kuntze	CHENOPODIACEAE	N	
Beta vulgaris L. var. cicla L.	CHENOPODIACEAE	N	
Beta vulgaris L. var. crassa L.	CHENOPODIACEAE	N	
Chenopodium album L.	CHENOPODIACEAE	N	Pperi; Pca.50
Chenopodium ambrosioides L.	CHENOPODIACEAE	N	

POLLEN TYPE *and component species*	FAMILY	PROVE-NANCE	POLLEN CLASS
Chenopodium carinatum R. Br.	CHENOPODIACEAE	N	
Chenopodium hircinum Schrad	CHENOPODIACEAE	N	
Chenopodium murale L.	CHENOPODIACEAE	N	
Salsicornia virginica L.	CHENOPODIACEAE	N	
Salsola kali L.	CHENOPODIACEAE	N	
CONVOLVULACEAE C3	**CONVOLVULACEAE**		**C3**
Perispermum albiflorum	CONVOLVULACEAE		C3
Perispermum menzeisii	CONVOLVULACEAE		C3
Cressa insularis	CONVOLVULACEAE		C3
Diospyros	**EBENACEAE**		**C3P3**
Diospyros hillebrandii (Seem.) Fosb.	EBENACEAE	E	C3P3
Diospyros sandwicensis (A. DC) Fosb.	EBENACEAE	E	C3P3
***Chamaesyce*-type**	**EUPHORBIACEAE**		**C3P3**
Chamaesyce annottiana (Endl.) Degener & I. Degener	EUPHORBIACEAE	E	
Chamaesyce atrococca (A. Heller) Croizat & Degener	EUPHORBIACEAE	E	C3P3
Chamaesyce celastroides (Boiss.) Croizat & Degener	EUPHORBIACEAE	E	C3P3
Chamaesyce celastroides var. *lorifolia* (A. Gray) Degener & I. Degener	EUPHORBIACEAE	E	C3P3
Chamaesyce clusiifolia (Hook. & Arnott) Arth.	EUPHORBIACEAE	E	C3P3
Chamaesyce degeneri (Sherff) Croizat & Degener	EUPHORBIACEAE	E	
Chamaesyce deppeana (Boiss.) Millsp.	EUPHORBIACEAE	E	
Chamaesyce halemanui (Sherff) Croizat & Degener	EUPHORBIACEAE	E	C3P3
Chamaesyce herbstii W.L. Wagner	EUPHORBIACEAE	E	
Chamaesyce kuwaleana (Degener & Sherff) Degener & I. Degener	EUPHORBIACEAE	E	
Chamaesyce multiformis (Hook. & Arnott) Croizat & Degener	EUPHORBIACEAE	E	C3P3
Chamaesyce olowaluana (Sherff) Croizat & Degener	EUPHORBIACEAE	E	
Chamaesyce remyi (A. Gray ex Boiss.) Croizat & Degener	EUPHORBIACEAE	E	C3P3
Chamaesyce rockii (C. Forbes) Croizat & Degener	EUPHORBIACEAE	E	
Chamaesyce skotsbergii (Sherff) Croizat & Degener	EUPHORBIACEAE	E	
Chamaesyce sparsiflora (A. Heller) Koutnik	EUPHORBIACEAE	E	
Euphorbia haeleeleana Herbst	EUPHORBIACEAE	E	C3P3
Chamaesyce albomarginata (Torr. & A. Gray) Small	EUPHORBIACEAE	N	
Chamaesyce hirta (L.) Millsp.	EUPHORBIACEAE	N	
Chamaesyce hypericifolia (L.) Millsp.	EUPHORBIACEAE	N	C3P3
Chamaesyce hyssopifolia (L.) Small	EUPHORBIACEAE	N	
Chamaesyce maculata (L.) Small	EUPHORBIACEAE	N	
Chamaesyce prostrata (Aiton) Small	EUPHORBIACEAE	N	
Chamaesyce thymifolia (L.) Millsp.	EUPHORBIACEAE	N	
Euphorbia cyathophora J.A. Murray	EUPHORBIACEAE	N	
Euphorbia graminea Jacq.	EUPHORBIACEAE	N	
Euphorbia heterophylla L.	EUPHORBIACEAE	N	
Euphorbia peplus L.	EUPHORBIACEAE	N	
Euphorbia pulcherrima Willd. ex Klotzsch	EUPHORBIACEAE	N	

POLLEN TYPE *and component species*	FAMILY	PROVE-NANCE	POLLEN CLASS
Claoxylon sandwicense	**EUPHORBIACEAE**		**CPstp C4P4,C5P5**
Claoxylon sandwicense Müll. Arg.	EUPHORBIACEAE	E	CPstp C4P4,C5P5
Acacia koa	**FABACEAE**		**Poly16Inap**
Acacia koa A. Gray	FABACEAE: Caesalpinioideae	E	Poly16Inap
Acacia koa A. Gray [*Acacia koaia* Hillebr.]	FABACEAE: Caesalpinioideae	E	Poly16Inap
FABACEAE undifferentiated	**FABACEAE**		**C3P3**
all members of family	FABACEAE		C3P3
Sophora chrysophylla	**FABACEAE**		**C3P3**
Sophora chrysophylla (Salisb.) Seem.	FABACEAE: Papilionoideae	E	C3P3
Prosopis	**FABACEAE**		**C3P3**
Prosopis pallida (Humb. & Bonpl. ex Willd.) Kunth	FABACEAE	N	
LAMIACEAE undifferentiated	**LAMIACEAE**		**Cstp; C3(4)**
all members of family	LAMIACEAE		C3
MALVACEAE undifferentiated	**MALVACEAE**		**P4**
all members of family	MALVACEAE		P4
Myoporum sandwicense	**MYOPORACEAE**		**C3P6**
Myoporum sandwicense A. Gray	MYOPORACEAE	I	C3P6
***Myrsine* C4**	**MYRSINACEAE**		**C(P)4**
Myrsine emarginata (Rock) Hosaka	MYRSINACEAE	E	C(P)4
Myrsine lanaiensis Hillebr.	MYRSINACEAE	E	C(P)4
Myrsine lessertiana A. DC	MYRSINACEAE	E	C(P)4
Myrsine petiolata Hosaka	MYRSINACEAE	E	C(P)4
Myrsine wawraea (Mez) Hosaka	MYRSINACEAE	E	C(P)4
***Metrosideros*-type**	**MYRTACEAE**		**C3P3**
Metrosideros macropus Hook. & Arnott	MYRTACEAE	E	C3P3
Metrosideros polymorpha Gaud.	MYRTACEAE	E	C3P3
Metrosideros polymorpha Gaud. var. *dieteri* J. Wyndham Dawson & Stemmermann	MYRTACEAE	E	C3P3
Metrosideros polymorpha Gaud. var. *glaberrima* (H. Lév.) St. John	MYRTACEAE	E	C3P3
Metrosideros polymorpha Gaud. var. *incana* (H. Lév.) St. John	MYRTACEAE	E	C3P3
Metrosideros polymorpha Gaud. var. *macrophylla* (Rock) St. John	MYRTACEAE	E	C3P3
Metrosideros polymorpha Gaud. var. *newellii* (Rock) St. John	MYRTACEAE	E	C3P3
Metrosideros polymorpha Gaud. var. *polymorpha*	MYRTACEAE	E	C3P3
Metrosideros polymorpha Gaud. var. *pseudorugosa* Skottsb.	MYRTACEAE	E	C3P3
Metrosideros polymorpha Gaud. var. *pumila* (A. Heller) J. Wyndham Dawson & Stemmerman	MYRTACEAE	E	C3P3
Metrosideros rugosa A. Gray	MYRTACEAE	E	C3P3
Metrosideros tremuloides (A. Heller) P. Knuth	MYRTACEAE	E	C3P3
Metrosideros waialealae (Rock) Rock	MYRTACEAE	E	C3P3
Callistemon rigidus R. Br.	MYRTACEAE	N	
Eucalyptus albens Benth.	MYRTACEAE	N	

POLLEN TYPE *and component species*	FAMILY	PROVE-NANCE	POLLEN CLASS
Eucalyptus amygdalina Labill.	MYRTACEAE	N	
Eucalyptus botryoides Sm.	MYRTACEAE	N	
Eucalyptus bridgesiana R. Baker	MYRTACEAE	N	
Eucalyptus calophylla R. Br.	MYRTACEAE	N	
Eucalyptus camaldulensis Dehnh.	MYRTACEAE	N	
Eucalyptus cinerea F.v. Muell. ex Benth.	MYRTACEAE	N	
Eucalyptus citiriodora Hook.	MYRTACEAE	N	
Eucalyptus cladocalyx F.v. Muell.	MYRTACEAE	N	
Eucalyptus cornuta Labill.	MYRTACEAE	N	
Eucalyptus crebra F.v. Muell.	MYRTACEAE	N	
Eucalyptus deanei Maiden	MYRTACEAE	N	
Eucalyptus deglupta Blume	MYRTACEAE	N	
Eucalyptus ficifolia F.v. Muell.	MYRTACEAE	N	
Eucalyptus globulus Labill.	MYRTACEAE	N	
Eucalyptus gomphocephala DC	MYRTACEAE	N	
Eucalyptus goniocalyx F.v. Muell. ex Miq.	MYRTACEAE	N	
Eucalyptus gummifera (Sol. ex Gaertn.) Hochr.	MYRTACEAE	N	
Eucalyptus marginata Donn ex Sm.	MYRTACEAE	N	
Eucalyptus microcorys F.v. Muell.	MYRTACEAE	N	
Eucalyptus paniculata Sm.	MYRTACEAE	N	
Eucalyptus pilularis Sm.	MYRTACEAE	N	
Eucalyptus raveretiana F.v. Muell.	MYRTACEAE	N	
Eucalyptus resinifera Sm.	MYRTACEAE	N	
Eucalyptus robusta Sm.	MYRTACEAE	N	
Eucalyptus rudis Endl.	MYRTACEAE	N	
Eucalyptus saligna Sm.	MYRTACEAE	N	
Eucalyptus sideroxylon A. Cunn. ex Woolls	MYRTACEAE	N	
Eucalyptus tereticornis Sm.	MYRTACEAE	N	
Eucalyptus viminalis Labill.	MYRTACEAE	N	
Eugenia uniflora L.	MYRTACEAE	N	
Feijoa sellowiana Berg.	MYRTACEAE	N	
Leptospermum flavescens Sm.	MYRTACEAE	N	
Leptospermum laevigatum (Sol. ex Gaertn.) F.v. Muell.	MYRTACEAE	N	
Leptospermum scoparium J.R. Forster & G. Forster	MYRTACEAE	N	
Lophostemon confertus (R. Br.) Peter G. Wilson & Waterhouse	MYRTACEAE	N	
Melaleuca quinquenervia (Cav.) S.T. Blake	MYRTACEAE	N	
Psidium cattleianum Sabine	MYRTACEAE	N	
Psidium guajava L.	MYRTACEAE	N	
Rhodomyrtus tomentosa (Aiton) Hassk.	MYRTACEAE	N	
Szigium cumini (L.) Skeels	MYRTACEAE	N	
Syzigium jambos (L.) Alston	MYRTACEAE	N	
Nestegis sandwicensis	**OLEACEAE**		**C3**
Nestegis sandwicensis (A. Gray) Degener, I. Degener, & L. Johnson	OLEACEAE	E	C3

POLLEN TYPE *and component species*	FAMILY	PROVE-NANCE	POLLEN CLASS
Plantago	**PLANTAGINACEAE**		**Pperi**
Plantago hawaiensis (A. Gray) Pilg.	PLANTAGINACEAE	E	
Plantago pachyphylla A. Gray	PLANTAGINACEAE	E	P4-5
Plantago princeps Cham. & Schlechtend.	PLANTAGINACEAE	E	P4-5
Plantago aristata Michx.	PLANTAGINACEAE	N	
Plantago australis Lam.	PLANTAGINACEAE	N	
Plantago debilis R. Br.	PLANTAGINACEAE	N	
Plantago lanceolata L.	PLANTAGINACEAE	N	Pperi; P8-12
Plantago major L.	PLANTAGINACEAE	N	
Rumex	**POLYGONACEAE**		**C3P3**
Rumex albescens Hillebr.	POLYGONACEAE	E	C3P3
Rumex giganteus W.T. Aiton	POLYGONACEAE	E	C3P3
Rumex skottsbergii Degener & I. Degener	POLYGONACEAE	E	C3P3
Rumex acetosella L.	POLYGONACEAE	N	C3P3
Rumex brownei Campd.	POLYGONACEAE	N	C3P3
Rumex crispus L.	POLYGONACEAE	N	C3P3
Rumex obtusifolius L.	POLYGONACEAE	N	C3P3
RANUNCULACEAE	**RANUNCULACEAE**		C3
All members of family	RANUNCULACEAE		C3
ROSACEAE undifferentiated	**ROSACEAE**		**C3P3**
all members of family	ROSACEAE		C3P3
Rubus	**ROSACEAE**		**C3P3**
Rubus hawaiiensis A. Gray	ROSACEAE	E	C3P3
Rubus argutus Link	ROSACEAE	N	
Rubus ellipticus Sm.	ROSACEAE	N	
Rubus glaucus Benth.	ROSACEAE	N	
Rubus macraei A. Gray	ROSACEAE	N	C3P3
Rubus niveus Thunb.	ROSACEAE	N	
Rubus rosifolius Sm.	ROSACEAE	N	
Rubus sieboldii Blume	ROSACEAE	N	
Rubus ulmifolius Schott var. *inermis* (Willd.) Focke	ROSACEAE	N	
Coprosma	**RUBIACEAE**		**C3P3(4)**
Coprosma cymosa Hillebr.	RUBIACEAE	E	C3P3(4)
Coprosma elliptica W. Oliver	RUBIACEAE	E	
Coprosma ernodeoides A. Gray	RUBIACEAE	E	C3P3(4)
Coprosma foliosa A. Gray	RUBIACEAE	E	C3P3(4)
Coprosma kauensis (A. Gray) A. Heller	RUBIACEAE	E	
Coprosma longifolia A. Gray	RUBIACEAE	E	C3P3(4)
Coprosma menziesii A. Gray	RUBIACEAE	E	C3P3(4)
Coprosma montana Hillebr.	RUBIACEAE	E	
Coprosma ochracea W. Oliver	RUBIACEAE	E	C3P3(4)
Coprosma pubens A. Gray	RUBIACEAE	E	
Coprosma rhyncocarpa A. Gray	RUBIACEAE	E	C3P3(4)
Coprosma ternata W. Oliver	RUBIACEAE	E	
Coprosma waimeae Wawra	RUBIACEAE	E	C3P3(4)

POLLEN TYPE *and component species*	FAMILY	PROVE-NANCE	POLLEN CLASS
RUTACEAE undifferentiated	**RUTACEAE**		**C3P3**
all members of family	RUTACEAE		C3P3
Dodonaea viscosa	**SAPINDACEAE**		**C3P3**
Dodonaea viscosa Jacq.	SAPINDACEAE	I	C3P3
Waltheria indica	**STERCULIACEAE**		**CPperi**
Waltheria indica L.	STERCULIACEAE	I	CPperi; C6P6(C5P5)
URTICACEAE undifferentiated	**URTICACEAE**		**Pperi (P2-15)**
all members of family	**URTICACEAE**		**P2**
***Pipturus*-type**	**URTICACEAE**		**P3**
Boehmeria grandis (Hook. & Arnott) A. Heller	URTICACEAE	E	P3
Hesperocnide sandwicensis (Wedd.) Wedd.	URTICACEAE	E	P3
Neraudia angulata R. Cowan	URTICACEAE	EG	
Neraudia kauaiensis (Hillebr.) R. Cowan	URTICACEAE	EG	
Neraudia melastomifolia Gaud.	URTICACEAE	EG	P3
Neraudia ovata Gaud.	URTICACEAE	EG	P3
Neraudia sericea Gaud.	URTICACEAE	EG	P3
Pipturus albidus (Hook. & Arnott) A. Gray	URTICACEAE	E	P3
Pipturus forbesii Kraj.	URTICACEAE	E	
Pipturus kauaiensis A. Heller	URTICACEAE	E	P3
Pipturus ruber A. Heller	URTICACEAE	E	
MONOCOTS			
Pritchardia	**ARECACEAE**		**S1**
Pritchardia affinis Becc.	ARECACEAE	E	
Pritchardia arecina Becc.	ARECACEAE	E	
Pritchardia aylmer-robinsonii St. John	ARECACEAE	E	
Pritchardia beccariana Rock	ARECACEAE	E	
Pritchardia forbesiana Rock	ARECACEAE	E	
Pritchardia glabrata Becc. & Rock	ARECACEAE	E	
Pritchardia hardyi Rock	ARECACEAE	E	
Pritchardia hillebrandii (Kuntze) Becc.	ARECACEAE	E	
Pritchardia kaalae Rock	ARECACEAE	E	
Pritchardia lanigera Becc.	ARECACEAE	E	
Pritchardia lowreyana Rock	ARECACEAE	E	
Pritchardia martii (Gaud.) H.A. Wendl.	ARECACEAE	E	
Pritchardia minor Becc.	ARECACEAE	E	S1
Pritchardia munroi Rock	ARECACEAE	E	
Pritchardia napaliensis St. John	ARECACEAE	E	
Pritchardia remota (Kuntze) Becc.	ARECACEAE	E	
Pritchardia schattaueri Hodel	ARECACEAE	E	
Pritchardia viscosa Rock	ARECACEAE	E	
Pritchardia waialealeana Read	ARECACEAE	E	
CYPERACEAE	**CYPERACEAE**		**PmonP1-4**
all members of family	CYPERACEAE		PmonP1-4
Cocos	**PALMAE**		**S1**
Cocos nucifera	PALMAE		S1

POLLEN TYPE *and component species*	FAMILY	PROVE-NANCE	POLLEN CLASS
POACEAE	**POACEAE**		**P1**
All members of family	POACEAE	I	P1
Tacca	**TACCACEAE**		**S1**
Tacca leontopetaloides	TACCACEAE		S1
FERN ALLIES			
Palhinhaea cernua	**LYCOPODIACEAE**		**L3**
Palhinhaea cernua (L.) Franco & Carv. Vasc.	LYCOPODIACEAE: Lycopodielloideae	I	L3
FERNS			
***Asplenium trichomanes*-type**	**ASPLENIACEAE**		**L1**
Asplenium acuminatum H. & A.	ASPLENIACEAE: Asplenioideae	E	L1
Asplenium kaulfussii Schlechtend.	ASPLENIACEAE: Asplenioideae	E	L1
Asplenium lobulatum Mett.	ASPLENIACEAE: Asplenioideae	I	L1
Asplenium trichomanes L.	ASPLENIACEAE: Asplenioideae	I	L1
Cibotium	**CYATHEACEAE**		**L3**
Cibotium chamissoi Kaulf.	CYATHEACEAE: Dicksonioideae	E	L3(1)
Cibotium glaucum (Sm.) Hook. & Arnott	CYATHEACEAE: Dicksonioideae	E	L3(1)
Cibotium menziesii Hook.	CYATHEACEAE: Dicksonioideae	E	L3(1)
Cibotium nealiae Degener	CYATHEACEAE: Dicksonioideae	E	
Cibotium x *heleniae* D. Palmer nothosp. nov. ined.	CYATHEACEAE: Dicksonioideae	E	
***Dryopteris*-type**	**DRYOPTERIDACEAE**		**L1**
Dryopteris acutidens C. Chr.	DRYOPTERIDACEAE: Dryopteridoideae	E	L1
Dryopteris crinalis (H. & A.) C. Chr.	DRYOPTERIDACEAE: Dryopteridoideae	E	L1
Dryopteris fusco-atra (Hillebr.) Robinson	DRYOPTERIDACEAE: Dryopteridoideae	E	
Dryopteris glabra (Brack.) Kuntze	DRYOPTERIDACEAE: Dryopteridoideae	E	L1
Dryopteris hawaiiensis (Hillebr.) H. Christ	DRYOPTERIDACEAE: Dryopteridoideae	E	L1
Dryopteris nuda Underw.	DRYOPTERIDACEAE: Dryopteridoideae	E	
Dryopteris sandwicensis (H. & A.) C. Chr.	DRYOPTERIDACEAE: Dryopteridoideae	E	L1
Dryopteris subbipinnata W.H. Wagner & R. Hobdy sp. nov. ined.	DRYOPTERIDACEAE: Dryopteridoideae	E	
Dryopteris tenebrosa W.H. Wagner sp. nov. ined.	DRYOPTERIDACEAE: Dryopteridoideae	E	
Dryopteris tetrapinnata W.H. Wagner & R. Hobdy sp. nov. ined.	DRYOPTERIDACEAE: Dryopteridoideae	E	
Dryopteris unidentata (H. & A.) C. Chr.	DRYOPTERIDACEAE: Dryopteridoideae	E	L1
Dryopteris wallichiana (Spreng.) Hyl.	DRYOPTERIDACEAE: Dryopteridoideae	I	
Dryopteris glabra (Brack.) Kuntze	DRYOPTERIDACEAE: Dryopteridoideae	E	L1

POLLEN TYPE *and component species*	FAMILY	PROVE-NANCE	POLLEN CLASS
Dryopteris hawaiiensis (Hillebr.) H. Christ	DRYOPTERIDACEAE: Dryopteridoideae	E	L1
Nephrolepis	**DRYOPTERIDACEAE**		**L1**
***Nephrolepis*-type undifferentiated**	**DRYOPTERIDACEAE**		**L1**
Nephrolepis cordifolia (L.) Presl	DRYOPTERIDACEAE: Nephrolepidoideae	I	L1
Nephrolepis cordifolia (L.) Presl [x] exaltata (L.) Schott var hawaiiensis	DRYOPTERIDACEAE: Nephrolepidoideae	E	
Nephrolepis exaltata (L.) Schott var. hawaiiensis W.H. Wagner var. nov. ined.	DRYOPTERIDACEAE: Nephrolepidoideae	E	L1
Nephrolepis [x] *medlerae* W.H. Wagner nothosp. nov ined.	DRYOPTERIDACEAE: Nephrolepidoideae	E	
Nephrolepis falcata (Cav.) C. Chr. cv. 'Furcans'	DRYOPTERIDACEAE: Nephrolepidoideae	N	
Nephrolepis hirsutula (Forst.) Presl cv. 'Superba'	DRYOPTERIDACEAE: Nephrolepidoideae	N	
Nephrolepis multiflora (Roxb.) Jarrett ex Morton	DRYOPTERIDACEAE: Nephrolepidoideae	N	L1
Dicranopteris	**GLEICHENIACEAE**		**L3**
Dicranopteris linearis (N.L. Burm.) Underw.	GLEICHENIACEAE	I	L3(1)
***Polypodium pellucidum*-type**	**POLYPODIACEAE**		**L1**
Polypodium "waianae kai"	POLYPODIACEAE	E	
Polypodium pellucidum Kaulf. var. *pellucidum*	POLYPODIACEAE	E	L1
Polypodium pellucidum Kaulf. var. *vulcanicum*	POLYPODIACEAE	E	L1
Polypodium pellucidum Kaulf.	POLYPODIACEAE	E	L1
Mecodium recurvum (Gaud.) Copel.	HYMENOPHYLLACEAE	E	L3(1); L1

Appendix D

VEGETATION OBJECTIVES - HILL OF THE WHALE SETTING FOR PU`UKOHOLĀ HEIAU

Bryan Harry and Others

Vegetation Objectives-- *Hill of the Whale* setting for *Pu`ukohola Heiau*

Legal Responsibility

The Act of Congress establishing the park stated:

> "That in order to restore and preserve in public ownership the historically significant temple associated with Kamehameha the Great, who founded the historic Kingdom of Hawaii . .
>
> [the]. . .site shall be administered, developed, preserved, and maintained in accordance with the provisions of the Act entitled "An Act to establish a National Park Service," approved August 25, 1916,[1] and the Act entitled "An Act to provide for the preservation of historic American sites, buildings, objects, and antiquities of national significance," approved August 21, 1935.[2]

It is clear from this legislation that the National Park Service's paramount responsibility here is to preserve and restore Pu`ukohola Heiau and its setting in perpuituity for the benefit of the public, and that this duty must not be compromised.

The Heiau Background

By 1790 Kamehameha ruled the west side of the Big Island. With good anchorages at Kailua and Kealakekua Bay he had a distinct advantage over foes who hadn't acquired advanced European technology and military strategy. During his various sorties on Molokai and Maui, Kamehameha's Hilo rival, Keoua, took advantage of his absence and lay waste to Hamakua and Kohala. Kamehameha returned and secured these lands but he did not defeat Keoua. It was during Keoua's retreat when part of his army, passing through K'au, suffocated during an extremely rare phreatic eruption of Kilauea--leading many to speculate that the Gods favored Kamehameha. Nonetheless

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[1] 39 Stat. 535.

[2] 49 Stat. 566: 16 U.S.C. 461 et seq.

Keoua held strong against Kamehameha's armies.[3]

Kamehameha consulted kahunas and one--Kapoukahi, wise in selecting sites--prophesied that if Kamehameha would re-build the temple at Pu`ukohola (Hill of the Whale) near Kawaihae and re-dedicate it to honor Ku-ka'ili-moku he would conquer the rest of the islands. Some even believe Kapoukahi foretold that "war shall cease on Hawaii when one shall come and shall be laid above the altar of Pu`kohola, the house of God."[4] Stalemated, even with his superior guns and weapons, Kamehameha followed his high priests' advice "and the construction of the Heiau on Puukohola was resumed with a vigour . ."[5] In 1790

> The building of this heiau was a great and arduous undertaking. Priests were everywhere about; they selected the site, determined the orientation, the dimensions, and the arrangement of the structure, and at every stage performed the ritualistic ceremonies without which the work could not be acceptable to the gods.[6]

Fornander states that an aged informant, who as a participant had actually carried stones during the construction, described thousands of people encamped on the hillside, their regulated eating periods, work shifts, break times and the numerous human sacrifices at various stages of the construction.[7]

Sporadic battles with previously conquered Chiefs briefly interrupted work on the heiau. A sea battle near Waipio Valley involved muskets and cannon. Kamehameha's fleet included his warship *Fair American* with its artillery commanded by John Young and Isaac Davis.[8] After this "battle of the red-mouthed gun" Kamehameha resumed work on the heiau and it was finished in the summer of 1791.

Keoua was enticed to the dedication of Pu`ukohala Heiau where he was slain and

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[3] Linda Wedel Green, *A Cultural History of Traditional Hawaiian Sites on the West Coast of Hawai`i Island*, National Park Service, 1993, p. 215-17.

[4] Samuel M. Kamakau, *Ruling Chiefs of Hawaii*, Honolulu: The Kamehameha Press, 1961, pp. 149-50; John Papa I`i, *Fragments of Hawaiian History*, Honolulu: Bishop Museum Press, 1959, p.17.

[5] Abraham Fornander, *An Account of the Polynesian Race: Its Origin and Migrations*, 3 vols., reprint (Rutland, Vt: Charles E. Tuttle, 1969), 2:327.

[6] Ralph S. Kuykendall, , (Honolulu: The University of Hawaii Press, 1947), p. 37.

[7] Fornander, *Account of the Polynesian Race*, 2:328.

[8] Russell A. Apple, "Davis, Young and Lopaka, The Cannon," in *Tales of Old Hawaii*, p. 47.

sacrificed at the dedication of the heiau[9]

The dedication of the heiau (and assassination of Keoua) gave Kamehameha undisputed control of the Big Island. By early 1795 Kamehameha succeeded in bringing all the islands but Kauai under his control. Many believe the successful completion and dedication of Pu`ukohola Heiau foreordained this outcome. Thus rests the case that Pu`ukohola Heiau is the single most significant structure in Hawaii.

Delimiting the Historical Site

This portion of the park's vegetation plan considers the significant Hill of the Whale setting for the famous heiau-- what landscape and vegetation should be our objective; what vegetation shifts could occur to upset this setting; the effect of such shifts on the visual and historical aspect of the heiau.

As a beginning, to consider a vegetation plan for the historical site itself, the park asked artist Herb Kawainui Kane for his suggestions regarding vangage points from which Pu`ukohola Heaiu was best displayed. Kane had made detailed studies of the heiau and brought both a historical interest and an artist's understanding to the problem. He suggested three principal vantage points for the heiau, and this thoughtful analysis of the heiau's setting:

> . . . nothing should be done to alter the unique character of the landscape. The open, generally barren condition best reveals the massive and sculptural land forms and the manner in which the heiau architecture rests upon these earth forms. I like to think of Pu'ukohola as a sculpture and the "hill of the whale" as its most ideal pedestal. When viewed from makai in the full afternoon sun, the strong earth colors of the rockwork and the softer analogous colors of the hill offer an impressive aesthetic experience, even to those who know nothing of the history of the place. Both heiau dominate the landscape, yet appear as part of it, as if they had grown out of it.[10]

Kane described a generally barren landscape of strong earth colors that prevails today. Figure 1 is a contemporary photo of existing conditions, which are the best and most appropriate setting fulfilling Kane's objective in the paragraph above. However, Figure 2 is the identical contemporary photo-- but with a tree background overshadowing the heiau silhouette. A major goal, therefore, is to thwart such vegetative succession, alien plant invasion, or human actions from transforming the heiau setting as seen from our principal heiau viewpoints. This is also in keeping with the earliest historic site descriptions of Pu`ukohola Heiau's setting.

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[9] Fornander, *Account of the Polynesian Race*, 2:328.

[10] Herb Kawainui Kane, letter to the National Park Service Pacific Area Director, June 10,1994.

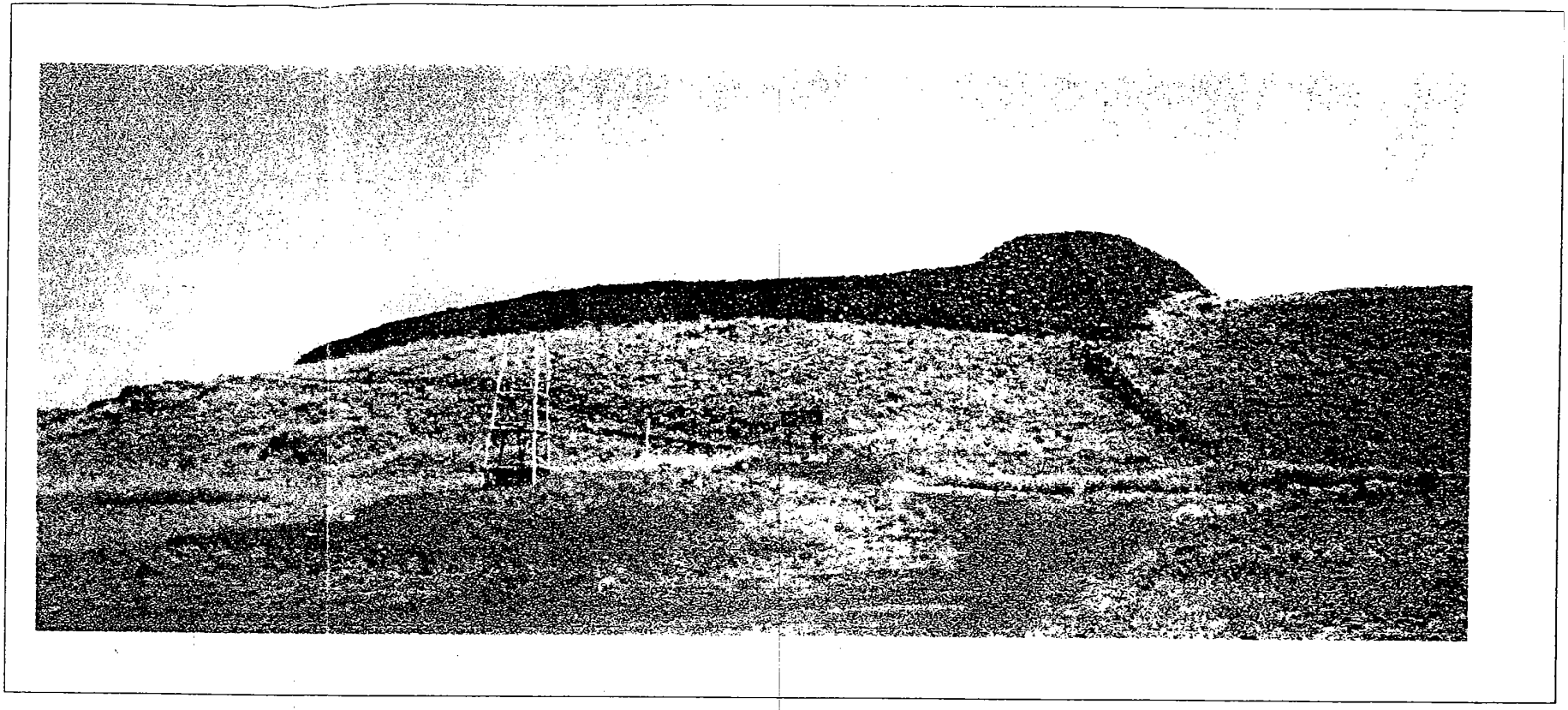

Figure 1. Skylined, Kamehameha's heiau is a powerful and dominant silhouette atop the Hill of the Whale.

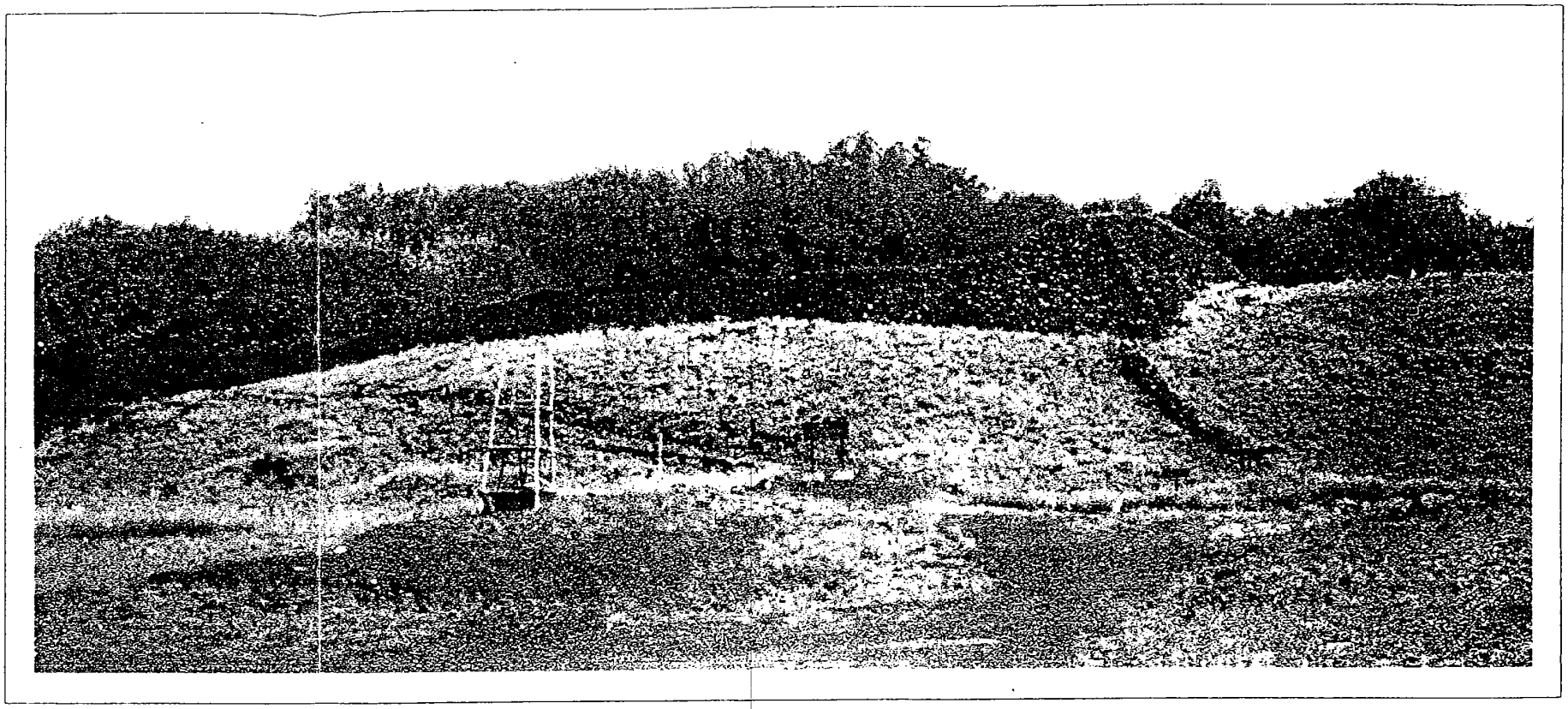

Figure 2. But if the heiau is overshadowed by a background of trees-- the heiau shrinks in power and position.

Earliest Historical Site Descriptions

Green summarizes all the known early descriptions of the heiau and its surrounding landscape.[11] Some are soon after the historic period of 1791. Isaac Iselin, on the *Maryland*, visited Kawaihae in the early 1800s:

> This Bay of Toeigh [Kawaihae] is very open . . . The country around it looks like a hilly barren desert; nothing grows within ten miles of itk except a few cocoanut trees, of which a fine grove stands near the beach.[12]

De Freycinet (on the French expedition (1817-20) described the landscape:

> Kohaihai [Kawaihae] is surrounded by even sadder, even drier grounds, if that is possible. Here in fact, not an atom of greenery appeared before our eyes. One could have said that it had been ravaged by fire. On an elevation near the southern section of the village, a morai [Mailekine] surrounded by a rock wall had the appearance of a European fort. Mr. Young's house, built in European style, could be seen farther off on the shore to the north.[13]

The first Western account of Pu`ukohola Heiau is by Menzies of the Vancouver expedition. He viewed the structure soon after its construction while it was still used for ceremonial purposes:

> I went towards a little marae [temple], with an intention to view the inside of it, but my guides told me it was strictly tabooed that they durst not indulge my curiosity without risking their own lives. They told me it was built about two years before in commemoration of a famous victory gained over Keoua, the last surviving issue of Kalaniopuu . . he invaded Kamehameha's territories, but meeting with a strong opposition from Keeaumoku and other chiefs, he was worsted in battle and he and eleven of his adherents were put to death near this marae. I was shown the spot on which this happened and where the bodies were interred, but their skulls are still displayed as

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[11] Green, *A Cultural History of Traditional Sites*, pp. 222-247.

[12] Isaac Iselin, *Journal of a Trading Voyage Around the World, 1805-1808.* New York: McIlroy and Emmet, n.d., p.72.

[13] Marion Kelly, ed., Hawai`i in 1819: *A Narrative Account by Louis Claude de Saulses de Freycinet*, trans Ella I. Wiswell. Pacific Anthropological Records No. 26 (Honolulu, 1931), p. 41.

ornamental tropies on the rail around the marae.

> This marae is situated on the summit of an eminence, a little back from the beach, and appears to be a regular area fifty or sixty yards square, faced round with a stone wall of considerable height, topped with a wooden rail on which the skulls of these unfortunate warriors are conspicuously exposed. On the inside, a high flat formed pile is reared, constructed of wicker work, and covered either with a net or some shite cloth. There were also enclosed several houses in which lived at this time five kahunas or priests with their attendants to perform the ritual ceremonies of the taboo, which had been on about ten days.[14]

Preserving the Hill of the Whale Landscape

The historical descriptions bear out Kane's analyses of the landscape at Pu`ukohala. The goal then of park management is to preserve, and, as necessary systematically restore the Hill of the Whale landscape.

As an early step we analysed viewplanes of the heiau from the three key viewpoints. Separate "visable areas" from the three key viewpoints were plotted on CAD/GIS using the parks 2' interval contour map. Sight lines were projected and contours were plotted for:

1) The limit of visable areas-- "0'"
2) Contour where the tip of 10' high vegetation came into view-- "10'"
3) Contour where the tip of 20' high vegetation came into view-- "20'"
4) Contour where the tip of 30' high vegetation came into view-- "30'"
5) Contour where the tip of 40' high vegetation came into view-- "40'"

Layers for the three individual key viewpoints were combined and the results portrayed in the CAD/GIS Sheets 1, and 2.

(captions)
Sheet 1. Vegetation in Zones 1 and 2.

Key Viewpoints

Zone 1, Area in direct view of one or more of the heiau key viewpoints

Zone 2, Area where tips of low vegetation when mature would also be visable from one or more key viewpoints.

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[14] Archibald Menzies, *Hawaii Nei 128 Years Ago*. Honolulu. New Freedom Press, 1920, pp. 56-57.

Sheet 2. Vegetation in Zones 3, 4, and 5.

Zone 3, Area where tips of vegetation at mature height of 10' would be visable from one or more key viewpoints.

Zone 4, Area where tips of vegetation at mature height of 20' would be visable from one or more key viewpoints.

Zone 5, Area where tips of vegetation at mature height of 30' would be visable from one or more key viewpoints.

(end of captions)

Sheets 1 and 2 then become the park's "hands on" maintenance and resource management direction of 'acceptable' and 'desirable' plant species to be preserved and/or restored. Desirable plants for each of the Zones would consist of species known to exist and characteristic of the Hill of the Whale historic period, the 1790's, and not exceeding height at maturity greater that shown for that zone. Tables tentatively listing these 'desirable' species for each of the zones are in Tables 1 through 5.

At present, we don't know how to restore the landscape to entirely 'desirable' species. Thus, we have a list of 'acceptable' alien serrogate species which in a landscape view, superficially look like the desired species. These species are listed in Tables 6 through 10. It is acceptable if we manage the landscape in the short term with these species, but we will commence small-scale experiments to develop management to shift the landscape species components for the acceptable serrogate species to the desired plant community assemplage. Some small experiments are suggested in the project proposals following the plant tables.

Table 1. A List of the Desirable Plant Species in the Zone 1 and 2 Heiau Landscape

Common Name	**Scientific Name**	**Comment**
Pili	Heteropogon contortus	the dominant plant
`Ilima	Sida fallax	commonplace
Pa`uohi`iaka	Jacquemontia ovalifolia	occasional
`Ihi	Portulaca cyanosperma	
Kakonakona	Panicum torridum	

Table 2. A List of the Desirable Plant Species in the Zone 3 Heiau Landscape

Common Name	Scientific Name	Comment
Pili	Heteropogon contortus	the dominant plant
`Ilima	Sida fallax	commonplace
Pa`uohi`iaka	Jacquemontia ovalifolia	occasional
`Ihi	Portulaca cyanosperma	
Kakonakona	Panicum torridum	
`Uhaloa	Waltheria indica	

Table 3. A List of the Desirable Plant Species in the Zone 4 Heiau Landscape

Common Name	Scientific Name	Comment
Pili	Heteropogon contortus	the dominant plant
`Ilima	Sida fallax	commonplace
Pa`uohi`iaka	Jacquemontia ovalifolia	occasional
`Ihi	Portulaca cyanosperma	
Kakonakona	Panicum torridum	
`Uhaloa	Waltheria indica	

Table 4. A List of the Desirable Plant Species in the Zone 5 Heiau Landscape

Common Name	Scientific Name	Comment

Management Practices and Experiments to Preserve and Restore Desired Vegetation